Towards an Optimal Product Portfolio of Liquid Fuels for the Malawi Energy Market:

Development of a strategic framework for enhancing pathways of ethanol production and use.

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy.

University of Bolton

By Evans Kacelenga

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Student Declaration

I declare that this thesis is my own work and does not incorporate without proper reference and acknowledgment any material previously published or written by another person.

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Date: April 2018

Abstract

Ethanol has been blended with petrol in Malawi for over thirty years. However the strategic decisions for energy security regarding liquid fuels conspicuously omit ethanol. Fossil fuels continue to occupy first place in spite of the acknowledged fact that fossils reserves are getting exhausted and unsustainable. The goal of the research was to develop a strategic framework for sustainably promoting ethanol production so as to make it a significant part of the liquid fuels portfolio and reduce fossil fuel dependence in Malawi. The purpose of the research was to find possible pathways for increasing the production of and use of ethanol.

Five pathways for increased ethanol production and use emerged from the interviews. An analysis of the interview findings identified three pathways for increased ethanol production. These were increasing feedstock for ethanol production, increasing sugarcane yields and increasing land under sugarcane. The analysis of the interviews identified two pathways for increasing ethanol use, one was government incentives and the other was the reduction of the ethanol price. Three interventions by government for achieving an optimal liquid fuel portfolio were identified as the introduction of ethanol driven vehicles, importation of flexi-fuel vehicles and the inclusion of ethanol tanks in the strategic fuel storage plan.

There has been no research which explored strategically increasing ethanol in the liquid fuels portfolio in the Malawi context, as such this represents a significant contribution to knowledge. Specifically seventeen sustainability criteria for ethanol production and use were ranked and six were found to be most relevant. The positive economic contribution criterion was seen as the most relevant by the respondents in contrast to the European Union, Brazil, America and elsewhere where green house gas (GHG) mitigation is number one. The land use change (LUC) or indirect land use change criterion had mixed responses signifying that it is not well known. Both the goal and purpose of the research were achieved. A strategic framework was developed and pathways identified.

Acknowledgements

This PhD journey was full of stop overs, pit stops and even breakdowns, just like life. At the end of this awesome journey I wish to express my gratitude to GOD the creator of the universe and sustainer of my life. Powerful and wonderful people have been instrumental in the completion of this journey. They comprise eminent scholars such as Professor Danny Morton my director of studies whose incisive insights kept me on the trot, Dr. Kondal Kandadi whose sharp questions raised the bar every time and Dr. Amos Chauma for his super editorial skills. I am also indebted to senior members of the energy sector who accepted to be interviewed for this project and provided vital information.

Family support was indispensable, so I thank my children Ritch, Thokozani and Shamiso for their whole hearted support for this project. Their wry humour kept the "motor running" and lifted me out of the breakdowns. Other relatives who have passed this way before like my sister Dr. Lillian Sankhulani and Dr. Eric Sankhulani must be recognized for their contributions and support.

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Evans Kacelenga

Contents

List of publications

The following paper was produced to disseminate some concepts and results from work undertaken by the author during the doctorate research study.

Conference Paper

1. Kacelenga, E. (2013). Towards an Optimal Product Portfolio of Liquid Fuels for the Malawi Energy Market: A Study to develop a strategic framework for a biofuel producer. “Proceedings of the strategic research for economic growth and social change in Malawi conference”. A University of Bolton conference which was held at Malawi Institute of Management from 21st-22nd June, 2013, Lilongwe.

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List of Abbreviations and acronyms

AA	Anhydrous Alcohol
ADB	African Development Bank
AfDB	African Development Bank
DoEA	Department of Energy Affairs
E10	Petrol ethanol blend with 10% ethanol by volume
E20	Petrol ethanol blend with 20% ethanol by volume
EDVP	Ethanol Driven Vehicle Project
ESCOM	Electricity Supply Commission of Malawi
ETHCO	Ethanol Company Limited
EU	European Union
GDP	Gross domestic product
GNI	Gross national income
ILUC	Indirect land use change
LPG	Liquefied petroleum gas
LUC	Land use change
MERA	Malawi Energy Regulatory Authority
MRA	Malawi Revenue Authority
NCST	National Commission of Science and Technology
NEP	National Energy Policy
NSO	National Statistics Office
OMC	Oil Marketing Company
PCL	Press Corporation Limited
PIL	Petroleum Importers Limited
RA	Rectified Alcohol
RS	Rectified Spirit
UN	United Nations

Chapter 1

Liquid fuels energy

1. Introduction

This study focuses on the development of a strategic framework for increasing ethanol production and use in Malawi. The Chapter introduces the main thrust of the research which is on how to sustainably increase the volume of ethanol in the liquid fuel portfolio in Malawi. It provides an overview of the road map of this research and outlines the lessons in the global, African and Malawi energy market scenarios. It further presents the energy challenges and prospects, Malawi energy mix, alternative energy and biofuels in Africa and Malawi, Malawi energy stakeholders, the problem statement, delimitations and assumptions A preview of the research process has been presented. The chapter concludes with an outline of the subsequent chapters in the thesis.

1.1 Introduction to energy

Energy is important for development in any country, therefore, the limits of growth and prosperity for virtually every economy are defined by the availability of reasonably priced energy (Goodman, 2004). The dependence of mankind on energy is shown by the keen interest on world potential supplies of various kinds of energy (Ahmad *et al.,* 2013). Energy is classified into different categories such as fossils and renewables. Fossil fuels include crude oil, coal and natural gas. Their origin is thought to be organic prehistoric plants and animals (Balat, 2008). According to Darvill (2012), alternative energy sources are those that are not fossils and include: hydroelectric, wind, solar, geothermal, nuclear and bio-fuels. Other definitions exclude the sources that have undesirable side effects such as nuclear.

Crude oil as the source of energy produced globally occupies a dominant place at thirty three percent (32%) followed by coal at thirty one percent (28%) and natural gas at twenty four percent (22%), while fourth place is biofuels (and waste) at only ten percent (10%) (IEA, 2015). A compelling reason for the use of biofuels, such as ethanol, is that fossil deposits are dwindling and irreplaceable (Umbach, 2010; Crooks, 2013; Hubbert, 1956).

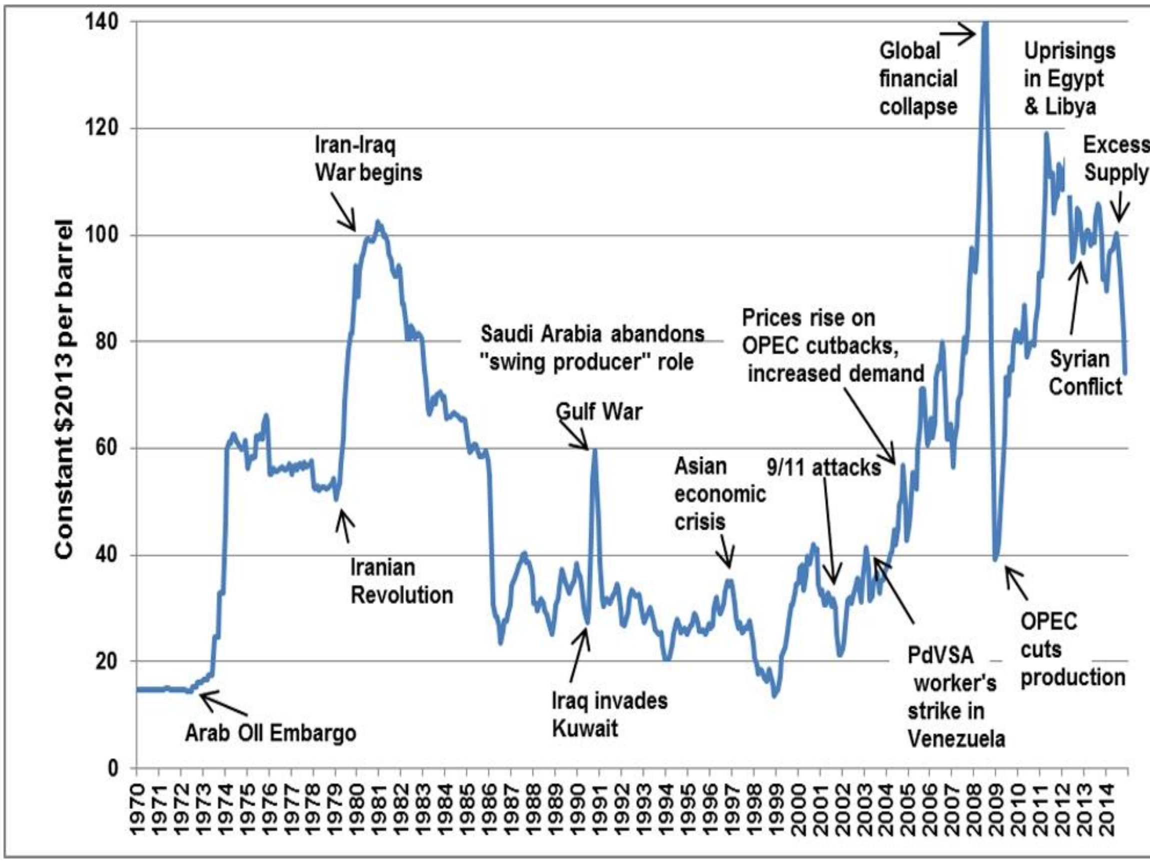
1.2 Global energy challenges and future prospects

In discussing energy challenges from a global perspective, oil is viewed as the most important energy resource, as Oettinger (2012, p.2) puts it, "Oil is one of the main drivers of our economies; more than a third of the European Union (EU) energy portfolio and almost all the energy we use in the transport sector is oil".According to Umbach (2010), the world is not confronted with an overall shortage of energy resources as end of the oil age is at least forty years from now. However, geopolitical factors such as crises and conflicts have the potential of preventing timely availability of energy resources (Umbach, 2010). In such instances, there would be severe world oil market ramifications which would require taking immediate measures to diversify to other energy sources such as renewable energy.

In the 1970s and 1980s, international concern and focus were directed towards oil and potential costs of supply disruption, associated with an over-dependence on oil imports. Hwang et al. (2011), states that the world oil price has been markedly volatile in the last three decades. The first Iraqi war affected oil prices, hence the crude oil price increase in 1991 and then the events of September 2011(9/11) in New York and the subsequent invasions of Afghanistan and Iraqi led to the spiralling crude oil price increase (Loon, 2010). Figure 1.2 aptly captures the world oil price volatility caused by wars and other events (DOE, 2015). These emphasise the need to search for alternative sources of energy.

Today, global oil demand is reflected in high oil prices caused by rising instability in many producer countries (such as Libya in 2012), global warming and fears of the approaching "peak oil" (Balat, 2008). These concerns have renewed interest in biofuels (Balat, 2008). According to the World Petroleum Council (2009), about 80% (eighty percent) of transport fuels are from fossil derivatives. As already mentioned, liquid fossil fuels include petrol, diesel, liquid petroleum gas (LPG), ethers from natural gas and menthol also produced from natural gas. Ethanol and hydrogen are the only non-fossil liquid fuels (World Petroleum Council, 2009).

Figure 1.2 Crude Oil Prices and Associated Events 1970-2014.



Source: DOE (2015)

It is interesting to note that the United Nations (UN) initiative for "sustainable energy for all" has the aim of securing universal access to energy and doubling, among other things, "the rate of renewables" by 2030 (Oettinger, 2012, p.2). The future of energy lies in renewable energy sources and in particular biofuels of which ethanol is a large part. Alternative energy and biofuels origins are discussed in the following section.

1.3 Alternative energy and biofuels origins

Renewable energy comes from natural resources such as sunlight, wind, rain, tides, waves and geothermal heat. Biofuels and biomass energy sources are considered renewables as well (Balat, 2008). The term biofuels is most commonly used to refer to liquid biofuels (bioethanol and biodiesel). These are fuels developed from specifically grown agricultural products. In the case of bioethanol it is agricultural products containing sugar, starch or cellulose (Larsson, 2006). According to Demirbas (2005, p.743), "Ethanol is a renewable green fuel. Ethanol is ethyl alcohol, grain alcohol, or C_2H_5OH. Ethanol is currently added to gasoline, but can be used pure. Benefits include reduced air pollution and reduced dependence on foreign oil." With regard to biodiesel, Sheehan et al. (1998, p.15) says "In its most general sense, biodiesel refers to any diesel fuel substitute derived from renewable biomass. More specifically, biodiesel refers to a family of products made from vegetable oils or animal fats and alcohol, such as methanol or ethanol". The exploitation of renewable energy presents itself as a sure source of energy for the future.

1.4 African Energy Markets

Africa is a key player in the international energy markets (Oettinger, 2012). According to Kaberuka (2013) Africa has significant energy resources which are under exploited. Thurnstrom et al. (2013) state that in 2010, Africa's oil production represented 12.4% of the world's total crude oil output. Africa's share of proven global crude oil reserves is 8.8% making the continent the fourth largest reserve globally after the Middle East, South and Central America, Europe and Eurasia. This continent is well endowed with crude oil and natural gas (Thurnstrom *et al.,* 2013). Energy demand is growing on the continent as more and more development takes place. The gap between potential oil reserves and production is tremendous and continues to grow as more reserves get discovered in countries like Ghana and Uganda because production facilities are not developing fast enough (Thurnstrom *et al*., 2013). These discoveries are also driving Malawi into oil exploration as well (Kambatata, 2012).

The route towards fully harnessing the benefits of having oil endowment in Africa is in good institutional governance, and sound economic policies (ADB, 2010). These are important conditions not only for efficient management of oil revenue but also for these countries to diversify away from crude oil dependence. The need for these countries to diversify is underscored by the direct linkage between high economic growth and the increases in oil prices, countries like Angola and Chad demonstrate this trend (Akpalu *et al.,* 2012).

One sector cited as providing a solution to the gap between energy demand and energy production is the sugar industry, where ethanol is presented as an alternative to fossil fuels (Calvacanti, 2011). Large sugar industries present power co-generation opportunities through the burning of bagasse to generate process steam and at the same time drive turbines to generate electricity for the plant or even supply the national grid (ADB, 2010).

Biofuels have an important role to play in reducing crude oil dependency (ADB, 2010). Hira (2010, p. 4) says "Biofuels can provide immediate relief and so are an attractive, if possibly interim, solution. Alcohol distilled from plant matter can be blended directly with gasoline to create ethanol, and a 20% or less alcohol blend can function well in a normal automobile engine". According to Almeida (2007), Brazil offers its expertise in ethanol to nations worldwide, especially developing countries that could produce biofuels in the context of oil dependency.

1.5 Challenges and the role of biofuels in Malawi

The projected energy profile (Table 1.5) for Malawi in 2000 shows biomass as the leading energy resource at ninety three percent (93%) with liquid fuel a distant second at three and a half percent (3.5%) (Department of Energy Affairs, 2003). While the projections represent a wish list by policy makers as to what the optimal energy portfolio ought to be, the reality is that liquid fuels continue to occupy a significant place, second only to biomass. The situation shown for the base year 2000, has not improved. According to NEP (2013), wood remains the primary source of energy at ninety three percent (93%). Davis et al*.,* (2011) puts the biomass dependence at ninety seven percent (97%). This calls for Malawi to explore other forms of energy if the wood cover is not to be depleted.

Hydro-electric generation is the major source of electricity in Malawi at three and a half percent (3.5%) penetration (ESCOM, 2013). Hydropower generates ninety four percent (94%) of Malawi's electricity with thermal generation accounting for just six percent (6%) (ESCOM, 2013). With a penetration of 3.5 % more investment is needed.

The National Statistics Office (NSO) reveals that petroleum imports at MK13.94 billion for the first half of 2010 topped the list of imports and accounted for 16.5% of the import bill for Malawi followed by medical supplies at 16.1% and fertilizer came third at 8.6% (National Statistics Office: Malawi, 2011). This shows that Malawi spends a lot of foreign exchange importing petroleum. The challenge is how to strategically manage, in general, the energy mix and in particular to optimise the liquid fuels portfolio for the benefit of the economy by promoting ethanol production and use. Table 1.5 shows the Malawi Government's desired energy mixes for the future between the base year 2000 and 2050. Ethanol is in the liquid fuels by virtue of blending with petrol (Department of Energy Affairs, 2003). It is also a renewable (Section 1.3).

Table 1.5 Malawi Energy Mix % Projections 2000 to 2050

	2000	2010	2020	2050
Biomass	93.0	75.0	50.0	30.0
Liquid fuels	3.5	5.5	7.0	10.0
Electricity	2.3	10.0	30.0	40.0
Coal	1.0	4.0	6.0	6.0
Other Renewables	0.2	5.5	7.0	10.0
Nuclear	0.0	0.0	0.0	4.0
TOTAL	100%	100%	100%	100%

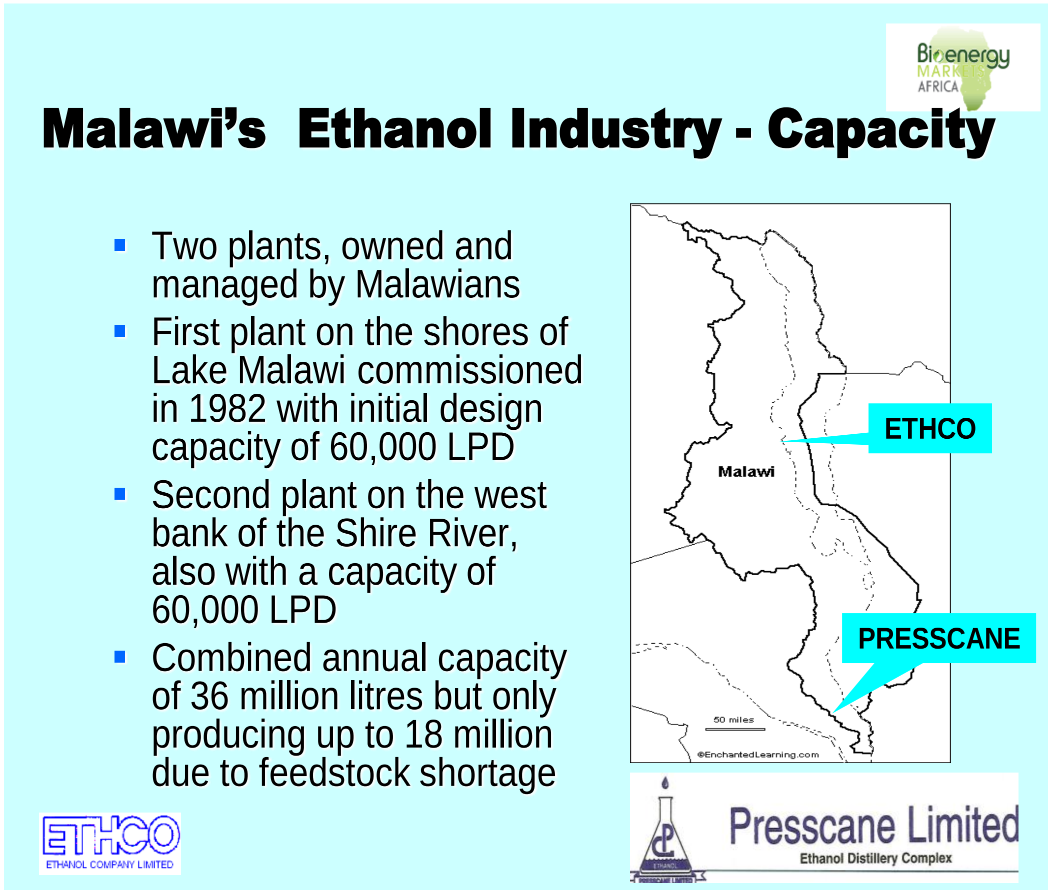
Source: Department of Energy Affairs, 2003

1.5.1 Malawi ethanol industry

In 1982, an ethanol plant called the Ethanol Company Limited (ETHCO) was established in Dwangwa in the central region of Malawi by presidential edict to produce fuel ethanol (also known as anhydrous alcohol (AA)) for blending with petrol at twenty percent (20% ethanol) (Jumbe *et al*., 2007).

PressCane Limited which was incorporated in 2001 is located in the south of Malawi and began operations in June, 2004, producing fuel ethanol. The two plants (ETHCO and PressCane Limited) make up the ethanol industry in Malawi (Jumbe *et al*., 2007). The two sugar estates, one in the centre and the other in the south of Malawi, are owned by Illovo Sugar Limited the sole supplier of molasses (raw material) to the two ethanol plants (Figure 1.5.1).

Figure: 1.5.1 Malawi Ethanol Industry



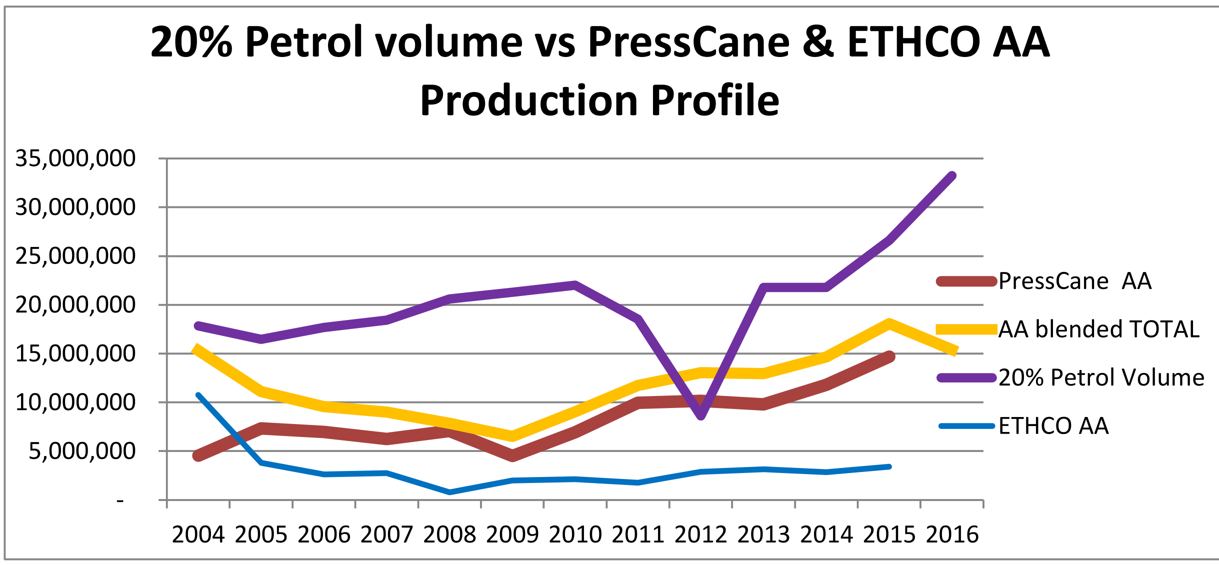
Source: Kacelenga (2010)

1.6 Malawi Energy Mix

Under the heading "The Malawi Energy Mix", the first MERA strategic plan (MERA, 2008, p.4) mentions ethanol in only one place as follows: *"Expanding the ethanol-petrol blending ratio, currently at 10:90, will further realize economic benefits of locally produced fuel ethanol. This will reduce the burden of foreign currency exerted by the bulk fuel imports. Further, MERA will support GoM's [Government of Malawi] Rural Electrification Programme. Supporting the generation and distribution systems of capacities up to 5MW in rural Malawi will enhance and improve rural livelihoods, welfare and also expand income generation opportunities".* As already alluded to, ethanol in Malawi is part of the energy mix via blending with petrol, although it is largely not recognized as such.

Ethanol volumes blended with petrol as mandated follow the imported petrol volumes (Malawi Government, 2010). When imported petrol volumes decline as happened in 2010 due to the foreign exchange shortage in Malawi, ethanol volumes in the liquid fuel portfolio also decline in keeping with the blend mandate (Sundu, 2012).

Figure 1.6 Profile of AA production PressCane and ETHCO



Source: Author's data analysis ETHCO & PressCane Ltd, 2015 Board Packs.

The graph shown in Figure 1.6 demonstrates this linkage and highlights the PressCane Limited (brown line) and ETHCO (blue line) fuel ethanol (AA) production volumes for the period 2004 to 2015. The brown line is closest to the yellow line signifying the larger contribution of AA by PressCane Limited to the total AA in the liquid fuels portfolio.

According to the Department of Energy Affairs (2003, p.73) "Malawi imports 97% of its refined petroleum, the balance is contributed by locally produced ethanol, sold directly to the oil companies for blending with petrol on a maximum 20:80 ratio of ethanol-petrol ……nearly 7% of the total liquid fuels market". This suggests that the 20% ethanol blended with petrol is nearly seven percent (7%) of the total imported fossil fuel volume. In 2004 according to PIL (2011), a total volume of about two hundred and fifty two (252) million litres of fossil fuel were imported versus fifteen (15) million litres of fuel ethanol (AA) produced, which makes fuel ethanol about six percent (6%) of the total liquid fuel market. On the other hand petrol volumes for 2004 were about eighty nine (89) million litres and twenty percent (20%) which is roughly eighteen (17.8) million litres ought to have been blended as per mandate. In this case only fifteen million litres were blended representing a sixteen percent (16%) shortfall of fuel ethanol required for blending.

1.7 The energy policy

The Malawi national energy policy vision states that "better, cheaper guaranteed supplies of petroleum products are needed" (Department of Energy Affairs, 2003, p.21). An admission is made by the Department of Energy Affairs (2003) that this has not been attained due to high costs, insufficient reserves and dependence on imports. The envisaged solutions are embedded in the vision as "improved efficiency in procurement, transportation and storage to reduce costs, together with investment in exploration as well as pipelines and storage facilities" (Department of Energy Affairs, 2003, p.21). The focus is clearly on petroleum products as the only ones in the liquid fuels portfolio. The glaring omission of biofuels is striking when it is considered that ethanol has been part of the liquid fuels portfolio since 1982 and the policy was only promulgated in 2003 (Jumbe et al., 2007; ETHCO, 1983). However inadequate blending of ethanol and petrol in the ratio of 20% ethanol and 80% petrol is mentioned as one cause of inefficiency in the liquid fuels supply (Department of Energy Affairs, 2003, p.28, p.30, p.73).

The Energy Policy (2003) classifies ethanol as a petroleum product, which it is not as ethanol originates from plants (biomass) This confusion ought to be addressed during a review of the energy policy document. Since the promulgation of the energy policy, changes such as mandatory blending (2009 Liquid Fuels and Gas Regulations) of ethanol and petrol, in the liquid fuels industry have presented opportunities for ethanol to occupy a more significant place in the liquid fuels portfolio since the overall blended volume of petrol is less than the mandated twenty percent (20%).

Inadequate blending could emanate from the oil marketing companies not blending at 20% as stipulated by law or from insufficient ethanol production or indeed both. According to Robinson and Wakeford (2013), the blending incentive of five Malawi kwacha per litre has not changed over the years while the price of petrol has continued to rise (Figure 1.2) further increasing the disparity between petrol and ethanol.

1.8 Malawi energy stakeholders

There are a number of government departments, agencies and the general populous who are stakeholders in the energy sector in Malawi. The government departments are involved generally in policy and revenue collection (taxation) from companies trading in energy including ethanol. These are:

a) The Malawi Energy Regulatory Authority (MERA)

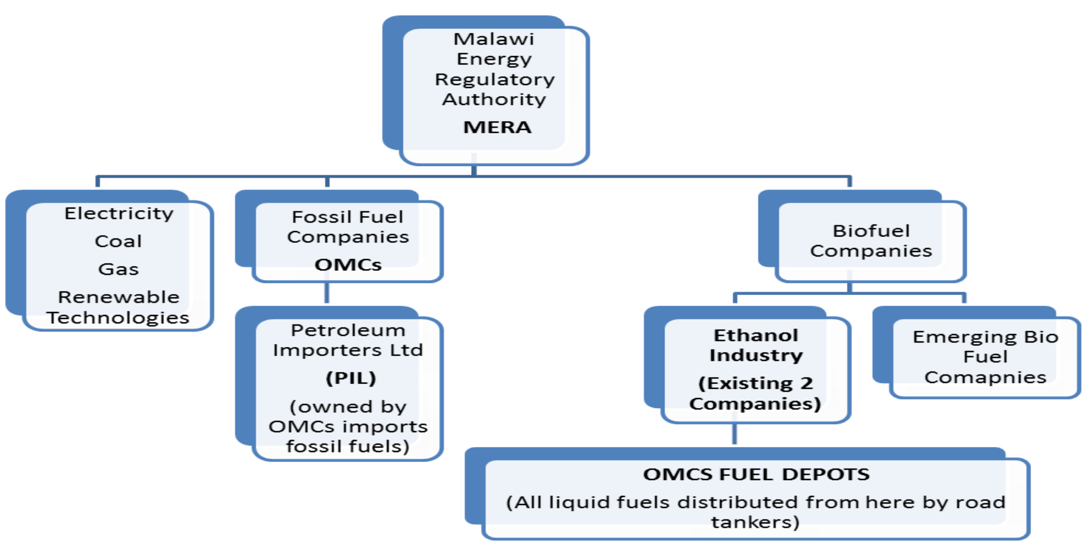
b) The Malawi Revenue Authority (MRA)

c) Department of Energy Affairs (DoEA)

Of the listed organisations MERA is the one charged with regulating and licensing of all energy activities including ethanol production.

The hierarchy in Figure 1.8 is in respect to regulation and licensing of various Malawi energy market stakeholders as shown in the first level. The second level depicts the liquid fuel distribution chain.

Figure 1.8 Malawi energy stakeholders



Source: Author

MERA regulates as follows:

a) production and pricing of coal and gas
b) electricity generation and distribution including pricing
c) renewable technologies distribution and pricing
d) fossil fuel companies (OMCs) distribution and pricing,
e) ethanol companies distribution and pricing

Figure 1.8 illustrates the relationships among the various stakeholders in the Malawi energy market.

The focus of this research is on the relationship between fossil fuels with specific reference to petrol and ethanol (a biofuel). Specifically, the research will interrogate how to reduce dependence on fossil fuels while increasing the production and use of ethanol.

1.9 Background to the problem statement

The Ethanol Company Limited (ETHCO) was established in 1982 (section 1.5.1) and PressCane Limited followed. PressCane Limited was incorporated in 2001 and is located in the south of Malawi. It began operations in June, 2004, producing fuel ethanol. The two plants ETHCO and PressCane Limited make up the ethanol industry in Malawi (Figure 1.8). The design capacity for each plants is 60,000 litres per day (60KLPD) of ethanol (Figure 1.5.1). The annual capacity is 36 million litres but only 18 million can be produced due to a shortage of raw material.

Most of the ethanol is used for blending with petrol in the ratio of twenty percent (20%) ethanol to eighty percent (80%) petrol. The remaining ethanol at ninety six and a half percent (96.5%) strength it is called rectified spirit (RS) or rectified alcohol (RA) or industrial spirit or hydrous ethanol. When coloured (denatured) it is used in hospitals as a disinfectant. Extra neutral alcohol (ENA) at ninety six and a half percent (96.5%) strength without the distinctive smell is used as a beverage.

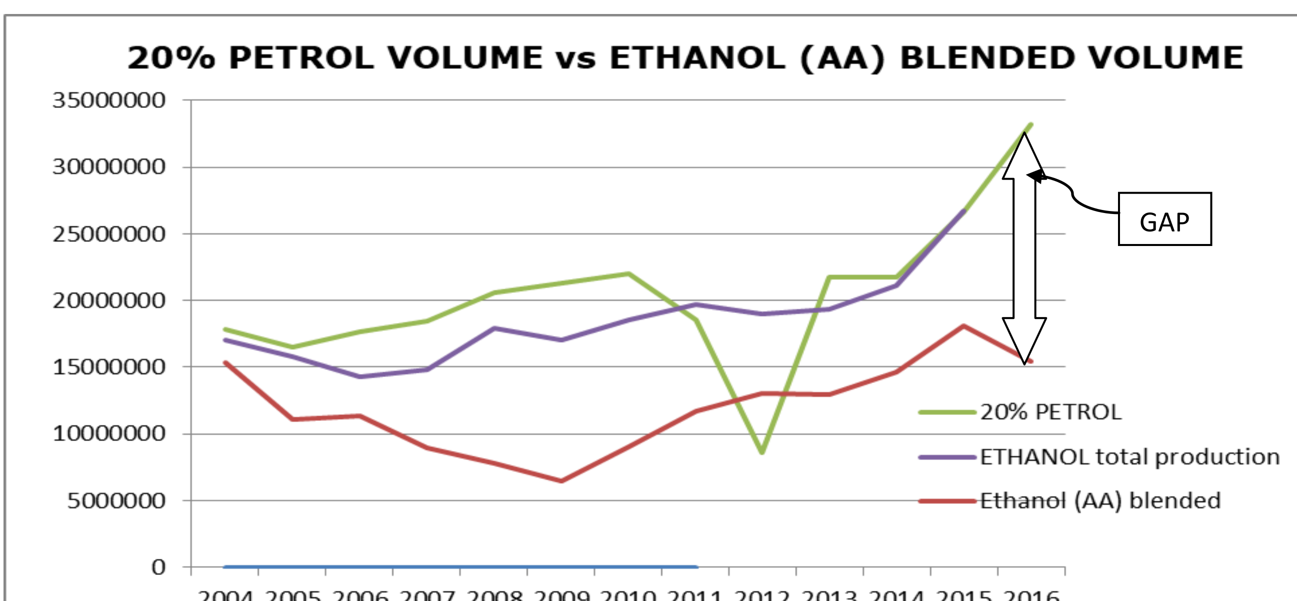
1.9.1 Problem Statement

There is evidence of a growing gap between the volume of petrol and the volume of ethanol for blending as shown in the graph in Figure 1.9.1. The graph has three lines as follows:

a) The green line is the 20% volume of the total petrol imported from 2004 to 2016. This represents the ideal volume of the ethanol required by the blend mandate which stipulates that petrol must have twenty percent (20%) by volume of ethanol in it. This mandatory blend is eighty percent (80%) petrol and twenty percent (20%) ethanol (Department of Energy Affairs, 2003; Chapter 1, section 1.7).
b) The purple line is the total ethanol produced (fuel ethanol (AA)), rectified spirit (RS) and extra neutral alcohol (ENA)) in the same period.
c) The red line is the actual fuel ethanol (AA) that was blended with petrol in the same period.

The analysis of Figure 1.9.1 shows that whereas the two ethanol companies in 2004 were producing nearly enough ethanol to meet the blending ratio of 20% as shown by the three lines almost coinciding in 2004, the gap has continued to widen. The volume of imported petrol (green line) has continued to rise whereas the volume of ethanol blended with petrol has decreased (red line). The sharp decline of petrol (green line) between 2010 and 2012 was due to the shortages of imported fossil fuels (Kambatata, 2012). The gap resumed when imports of fuel normalised (Figure 1.9.1).

Figure 1.9.1 Ethanol volume trend versus petrol 2004 to 2016



Source: Author

As noted already in the years 2005 to 2010 the volume of AA (red line) declined due to the change of blending ratio from twenty percent (20%) to ten percent (10%). This changed in December, 2010 when the blend ratio was returned to 20% and the AA volumes increased (Malawi Government, 2010). The gap between the 20% volume of imported petrol and AA volume persists.

The problem that this research is dealing with therefore is: *"How can Malawi sustainably increase the volume of ethanol produced and used in order to reduce dependence on expensive fossil fuels"?*

1.10 Research questions

From the conception and literature review of thesis research the initial key questions that the researcher sought to answer are: How can Malawi move away from being fossil fuel dependent to biofuels and how can the use of ethanol be increased in Malawi?. The following are the specific initial questions:

a) What policies exist to coordinate bio-fuels and fossil fuels?
b) What should be done to make ethanol more significant in the Malawi liquid fuels portfolio?
c) How can the use of ethanol be increased?
d) What criteria should be considered in determining biofuel sustainability?

These initial questions were confirmed in the research through literature review. As the literature review progressed new questions emerged and were added to the questionnaire (Appendix 1).

1.11 Research Goal and Objectives

The goal of this research is to develop a strategic framework for sustainably promoting ethanol production and use in order to make ethanol a significant part of the liquid fuels portfolio and reduce fossil fuel dependence in Malawi. The purpose of the research is, therefore, to find pathways for increasing the production and use of ethanol in Malawi The specific objectives of the research are to:

a) Determine the level of awareness on biofuel policy and strategy.
b) Find pathways of increasing ethanol production to make it significant in the liquid fuel portfolio.

c) Find pathways for increasing the use of ethanol to make it significant in the liquid fuel portfolio.
d) Investigate sustainability criteria for ethanol production and use.

The framework will facilitate the volume growth of ethanol and its inclusion as a liquid fuel whether in blended form or as a standalone fuel to expand the liquid fuel product portfolio while reducing the volume of imported petroleum liquid fuels. Liquid fuel imports in Malawi have the largest share of imports (Section 1.5; National Statistics Office: Malawi, 2011).

Clearly, achieving an optimal liquid fuel portfolio would lower the fuel import bill while increasing the fuel volume available and at the same time releasing resources to other vital sectors such as health and education.

1.12 Delimitations of the research

The focus was on ethanol in the liquid fuels portfolio. Three types of ethanol exist on the Malawi market as described in section 1.9. The research is specifically concerned with fuel ethanol. Data generation was primarily by semi-structured interviews, self-administered questionnaires, and archival searches and through observations at meetings attended by the author. The targeted respondents who were energy strategists were interviewed and concurrently the interviewees completed a self administered questionnaire. Secondary data came from archival searches of Government and company documents, such as annual reports and minutes of meetings attended by the researcher as well as minutes of proceedings at the annual World biofuels Markets conferences in Brussels, regional Green Power biofuel conferences also attended by the researcher. It was noted that biofuels literature is limited for Malawi.

The research focused on Malawi though it drew from lessons from other countries.

1.13 Assumptions

The Malawi ethanol industry is made up of two companies: Ethanol Company Limited (ETHCO) and PressCane Limited. As mentioned earlier, both companies have the same majority shareholder, Press Corporation Limited (PCL) (1.5.1). As a consequence, the management contract for both companies is with PCL. Liquid fuel importers, distributors and regulators all interact with these two companies for their fuel ethanol requirements. The assumptions on this basis are:

a) That the two ethanol companies have similar market challenges due to having the same major shareholder.
b) That the interviewees have knowledge of ethanol as a liquid fuel by virtue of their high positions in the energy sector in general and the liquid fuels in particular.

1.14 Organisation of the thesis

Chapter one presents the thrust of the study, the global, African and Malawian energy market trends, challenges and the roles of ethanol, meaning of key words, the problem statement, research questions and the organisation of the thesis.

Chapter two presents the literature review on the history of biofuels in the liquid fuels energy mix, particularly ethanol. Global coverage of leading ethanol producers such as Brazil, India, and the EU among others is made. The relevance and applicability to Malawi, a significant ethanol producer on the African continent is thus made. The role of strategic management and systems theories in establishing the position of ethanol in the liquid fuels energy market is explored.

Chapter three deals with the research purpose and approach followed by the research paradigm and methodology, next is the research strategy. A justification of the mixed methodologies is made and concludes by a description of the data collection methods, mainly interviews, questionnaires and participant observations.

Chapter four presents the findings from the research and analyses the data objective by objective. Other findings not connected to the objectives are discussed and finally a summary of the findings are shown in a diagram.

Chapter five consists of the synthesis of the findings and the recommendations are presented. From these a framework is developed following on from the findings in Chapter four. A summary closes this chapter.

Chapter six presents the conclusions of the research. The research purpose is restated along with the objectives. The pathways identified in the research are repeated in summary. The theoretical and practical knowledge contributions are presented. Further research areas and recommendations are discused and a summary closes the chapter.

1.15 Summary.

This chapter has presented the main thrust of the research as seeking a strategic framework of how to increase ethanol production and hence the significance of ethanol in the liquid fuels portfolio in Malawi. This leads into the literature review chapter. The literature review followed and sought to understand past efforts and how liquid fuels specifically biofuels have been strategically managed elsewhere and lessons learned.

Chapter 2:

Literature Review

"If you want to see what ethanol as a fuel can do, watch the Indianapolis 500 on Memorial Day. All Indy League Racing Circuit cars run on 100% ethanol. The fastest, most advanced race cars in the world run on ethanol". (Fred Linn, 2014).

2.1 Introduction

This chapter reviews literature pertaining to energy sources with the objective of increasing the production and use of biofuels in the liquid fuels portfolio in Malawi. The goal of increasing the production and use of biofuels is to reduce dependence on fossil fuels especially petrol and diesel. The coverage of the review begins with a definition of key terms used in the research. It goes on to explain the term conventional, alternative energy and global energy challenges. The review then focuses on the African and Malawi energy scenarios with emphasis on the Malawi energy policy, the liquid fuel industry and the role of biofuels in addressing energy challenges in Malawi. The literature review then addresses the four objectives of the study. Specifically the review establishes what has been researched on in the past, what the current thoughts are with regard to the objectives and what are the gaps. Last the review also generates research questions from the literature review. In view of the fact that the focus of the research is a Strategic Framework of Malawi for increasing the production and use of biofuels, the researcher reviews some frameworks from other countries including Brazil, China, USA, India and the European Union among others seeking their relevance and applicability to Malawi. Last but not least the literature review looks at the advantages and disadvantages of biofuels.

2.2 Definition of terms.

There are important terms that are found in this research. These terms and concepts were defined in order to provide the basis for understanding and following up on the research. This section, therefore, presents definitions of the terms used in this research. The terms are fossil fuels, alternative energy, renewable energy, biofuels, liquid fuels, and optimal product portfolio.

a) **Fossil fuels**

Fossil fuel is a general term for buried combustible geologic deposits of organic materials, formed from decayed plants and animals that have been converted to crude oil, coal, natural gas (also referred to as gas), or heavy oils (World Petroleum Council, 2009). Fossil fuels are finite and will be exhausted sooner or later, hence the search for alternative fuels (Hubbert, 1956). Section 2.4.2, deals with this aspect.

b) **Alternative energy** is any energy source that is an alternative to fossil fuels (Chapter 1, section 1.3). Alternative energy includes hydroelectric, nuclear, wind, biofuels, solar and geothermal (IEA, 2015). This is discussed in more detail in Section 2.5.

c) **Renewable energy** comes from natural resources such as sunlight, wind, rain, tides, waves and geothermal heat. Biofuels and biomass energy sources are considered renewables as well (Balat, 2008).

d) **Biofuels** are renewable energy sources that are produced from recently living organisms or their byproducts (Balat, 2008; Biofuelindonesia, 2007). The term is most commonly used to refer to liquid biofuels, bioethanol and biodiesel (Balat, 2008). The increasing and waning of interest in biofuels is directly connected to fossil fuel developments (Chapter 1, section 1.3; Chapter 2 sections 2.5, 2.8, 2.9).

e) **Liquid fuels** in Malawi include fossil products such as petrol, diesel, paraffin, aviation gas and ethanol the only biofuel (Department of Energy Affairs, 2003).

f) **Optimal product portfolio** refers to the total volumes of petrol, diesel, paraffin, aviation gas and biofuels that best fit the energy requirements of the nation at anyone given time (Chen, 2013). Portfolio in this study is a synonym of liquid fuel mix.

The terms defined occur regularly in the literature reviewed and the discussion that ensues. These provide a platform for understanding the various issues raised in this research. The next section explains conventional energy and alternative energy sources.

2.3 Conventional Energy

This section describes the main conventional energy sources and alternative energy sources in the context of dwindling fossil resources. Fossil fuels include coal, oil and gas while alternative energy sources cover non-fossil sources such as biofuels, wind, solar, geothermal and, hydroelectric.

2.3.1 Coal

According to the International Energy Agency (IEA) (2013), over forty percent (40%) of the world's electricity is generated from coal. Coal is the second primary energy source in the world after oil (IEA, 2015). Industry uses coal extensively for steam generation and for heating purposes (Yilmaz, 2008). Electricity continues to be largely generated from coal. Many growing economies are powered by coal, for example, China (IEA, 2013) and Turkey (Yilmaz, 2008).

Concerns over the environmental impact of use of coal, particularly carbon emissions, have elicited a number of responses. According to the Coal explorer report (2012), the reaction in India has been to retire old inefficient coal electricity generators and move towards natural gas combined cycle plants (CCP). Other responses include a drive for more efficient coal generators as opposed to abandoning coal plants altogether, retrofitting the older plants and investing in carbon capture and storage (CCS) technologies (IEA, 2013). These efforts according to Allen (2012, p.23) have “ramifications” beyond normal business, due to concerns on global warming. Climate change, referred to as global warming in older literature, issues have been cited as the reason for the promotion of biofuel use (Barber et al., 2008; Demirbas, 2008; European Parliament Council, 2009; Balat, 2011). The promotion of sustainable biofuel production and use is presented in contrast to unsustainable fossil fuel use. Indeed biofuels are a strong alternative to fossil fuels.

2.3.2 Oil

According to Demirbas (2010), conventional fossil fuels are scarce and this is driving up their prices as well as increasing the interest in renewables. Crooks (2009) points out that oil consumption in developed countries may actually have passed its peak. The main oil producing areas are volatile geopolitically and thus increasing the need to find alternative energy sources (Nkomo, 2009). George Bush (2006) observed that oil is not just about energy it is now a security issue because the regions that export oil are mostly at war.

Corro and Ayala (2008) state that conventional fossil fuels are causing concern due to their global warming effects by producing green house gases (GHGs) any of the atmospheric gases that absorb infrared radiation produced by solar warming of the earth's surface. They include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor. This concern is fueling interest in bioethanol and diesel blends as a means for harmful emissions abatement. According to Corro and Ayala (2008, p.3537) “Bioethanol is considered by many as one of the most important alternatives to gasoline and diesel”. According to Demirbas (2010), the growing emissions of combustion-generated pollutants, which generate greenhouse gases and their increasing costs, make biomass sources more attractive hence the resurgence of the interest in biofuels. The historical connection of fossils and biofuels is well established (Chapter 2, section 2.1; Loppacher and Kerr, 2005; Demibras and Balat, 2006; Biofuelindonesia, 2007).

2.3.3 Natural gas

Gas, oil and coal are used to produce power. These fuels are generally burned to heat water, with the resulting steam being used to drive a turbine to generate electricity (Institution of Mechanical Engineers, 2015). According to the Institution of Mechanical Engineers (2015), the largest proven gas reserves are in the Middle East followed by Russia. Burning gas is considered cleaner than burning coal or oil (Coal explorer report, 2012). According to Darvill (2012), the leading preferred fossil energy source is natural gas. The IEA quoted by the Coal explorer report (2012) says natural gas is being preferred over coal and oil because it is cheaper and has lower GHG emissions rendering environmental compliance costs lower. The availability of highly efficient natural gas power plants is yet another advantage.

2.3.4 Alternative energy and biofuels

In the preceding sections conventional energy including coal, oil and natural gas were discussed. In this section the researcher discusses alternative energy with emphasis on biofuels. Alternative energy is any energy source that is an alternative to fossil fuels (Chapter1, section 1.3). Alternative energy comprises the renewables which include wind, biofuels, solar, hydroelectric, nuclear, and geothermal are a very small part of the global energy mix at one percent for wind and much less for biofuels, solar and geothermal (Darvill, 2012). Economic, political and environmental factors are driving the shift from fossils to alternative energy sources including biofuels. The researcher, excludes the other forms of alternative energy and delimits the research to biofuels, specifically ethanol in the rest of the study. Biofuels are, therefore, presented.

The most common types of biofuel are originated from specifically grown agricultural products. This includes:

a) Corn and Soybeans, primarily in the United States;
b) Flaxseed and Rapeseed, primarily in Europe;
c) Sugar Cane in Brazil;
d) Palm Oil in South-East Asia;
e) Jatropha Curcas, primarily in India.

Biofuel can also come from biodegradable outputs from industry, agriculture, forestry and households. This includes straw, timber, manure, rice husk, sewage, biodegradable waste, and food leftovers as shown in Table 2.3.4 (Sun and Cheng, 2005).

Table 2.3.4 Biodegradable outputs

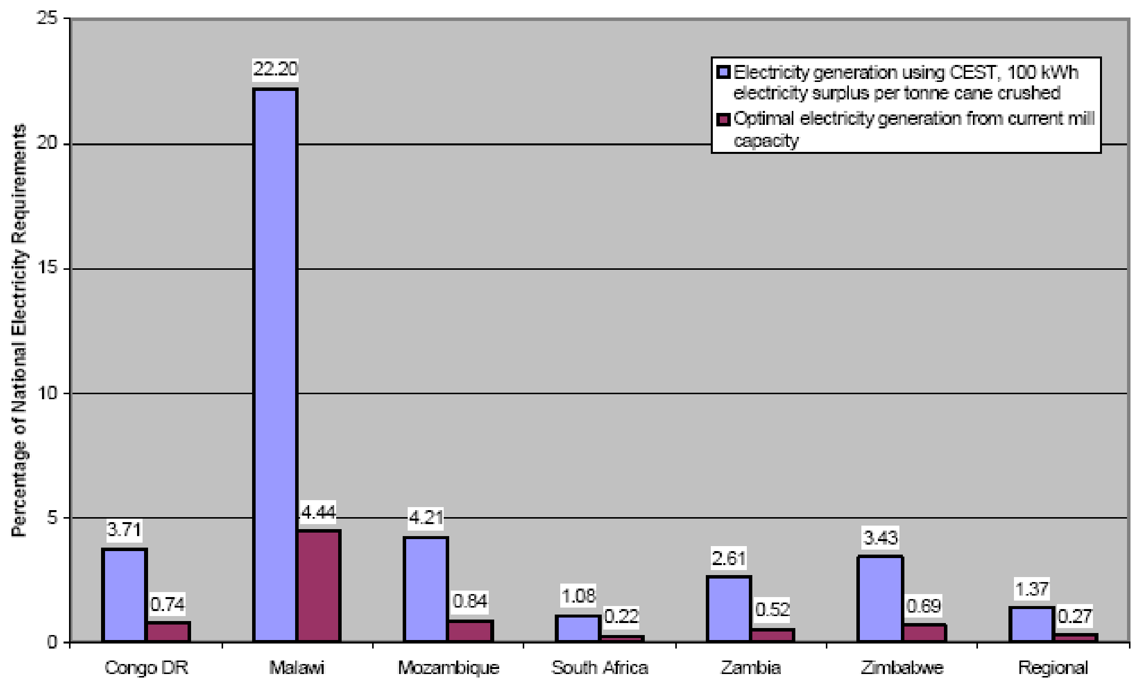
Bioethanol pathways from different raw materials	
Raw material	Processing
Wood	Acid hydrolysis + fermentation
Wood	Enzymatic hydrolysis + fermentation
Straw	Acid hydrolysis + fermentation
Straw	Enzymatic hydrolysis + fermentation
Wheat	Malting + fermentation
Sugar cane	Fermentation
Sugar beet	Fermentation
Corn grain	Fermentation
Corn stalk	Acid hydrolysis + fermentation
Sweet sorghum	Fermentation

Source: Sun and Cheng (2005**)**.

Ethanol has emerged in the past decade as the most significant among the various alternative fuels or fuel-vehicle systems that have entered the market (Sorda et al., 2010; Hira, 2010; Lamers et al., 2011). In addition to Brazil, global biofuels market expansion is attributed to the EU and U.S. biofuel mandates (European Parliament, Council, 2009; US-EPA, 2010). The fuel ethanol market has also been analysed as a strategic investment for Least Developed Countries (LDCs) in relation to energy security and climate mitigation (Pacini and Batidzirai, 2012; Batidzirai and Johnson, 2012). More than twenty-five countries have legislation related to blending of ethanol and/or biodiesel (Sorda et al., 2010).

ADB (2010) argues that the gap between world energy supply and demand can be filled by alternative energy sources. Oettinger (2012) concurs and adds that biofuels are a pathway to reduce fossil oil dependence. Batidzirai (2007) shows the potential electricity (alternative energy) generation using condensing extraction steam turbine (CEST) technology from the bagasse coming from existing sugarcane mills in the SADC (Southern African Development Community) region which includes Malawi (Figure 2.3.4). Malawi's potential, in this analysis, is the highest in the SADC region.

Figure 2.3.4 Potential bagasse based electricity generation



Source: Batidzirai (2007)

The green belt initiative (GBI) is aimed at increasing sugar production; however this will also increase the bagasse available for electrical power generation (Government of Malawi, 2011).

The energy scenario for direct access to electricity stands at two percent (2%) for the global rural population, while it is at twenty percent (20%) for the whole population on the African continent (Rastogi, 2011). According to Rastogi (2011), if Africa were to realise its potential in renewable energy, the continent's dependency on oil would be reduced, food and energy security would improve, the industrial sector energy needs would be boosted, GHGs would be reduced and land restoration would be promoted. Other benefits would be poverty alleviation by improving access to energy in rural areas, boosting local agriculture production, giving farmers access to additional markets and revenues, and generating jobs. Assisting farmers implies some form of subsidy and political imperatives indicate that farm input subsidies will remain a key strategy for increasing agricultural productivity in Malawi (Chibwana and Fisher, 2011).

According to Oettinger (2012) fossil fuels have negative impacts on the environment and biofuels present an alternative. However energy globally is viewed from the oil perspective. That is why the researcher has reviewed conventional energy first including coal, oil and natural gas and then discussed alternative energies with emphasis on biofuels. The sections that follow present the context of oil dominance in the global energy mix.

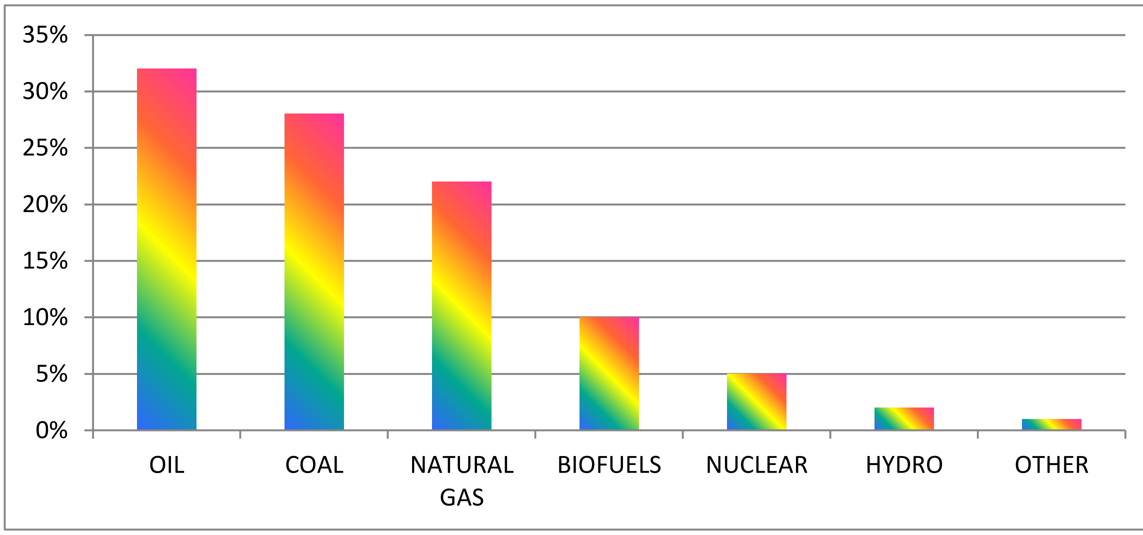
2.4 Global Energy Markets

World energy markets revolve mainly around fossil fuels (Ahmad *et al.,* 2013). The finite oil resource is the driver for renewable energy specifically biofuels. A description of the global energy composition is presented followed by a discourse on peak oil to explain the dwindling oil resource.

2.4.1 Global energy composition

Oil, at thirty two percent (32%) is a leading component in the energy mix globally as shown in Figure 2.4.1. The renewables, biofuels, nuclear, hydro and others are a small part of the global energy mix (IEA, 2017). The International Energy Agency, however, predicts that the world's energy needs will expand by 45% between 2008 and 2030 (International Energy Agency, 2008). The growing energy needs should be the impetus for developing the alternative energy sources including biofuels in the quest to reduce fossil oil dependence (Chapter 1, section1.3).

Figure 2.4.1 Global Energy Production Profile 2015



Source: IEA (2017)

A reduction on oil dependence increases energy security thus reducing oil supply vulnerability. According to Nkomo (2010) energy security is affected by a number of factors such as collusion among oil exporting countries, insufficient diversification and political vagaries among others. Gonsalves (2006, p.13) says, "Renewable energy, including biofuels, can help diversify energy supply and increase energy security". Jamieson (2011) submits the following reasons for the initial pursuit of biofuels:

a) Reducing GHG emissions from transport
b) Bringing employment & investment to poor rural areas
c) Increasing energy security
d) Generating revenue for developing countries
e) Reducing financial support for 'unfriendly' oil nations
f) Paving the way for a 'Green Economy'

While the EU biofuel agenda is driven by the desire to reduce GHGs citing job creation and development for poor economies; increasing energy security remains a powerful incentive in this pursuit (Jamieson, 2011).

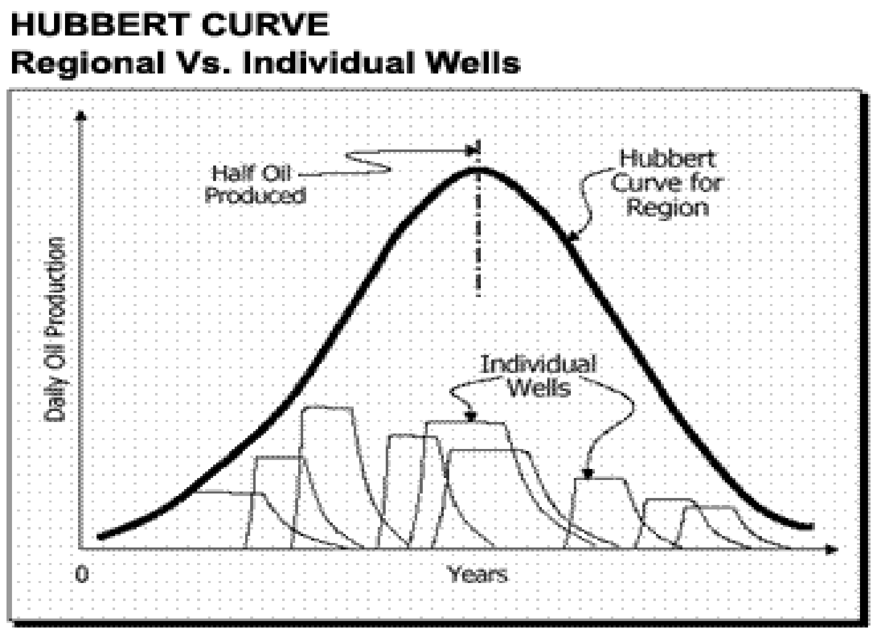
Disruption of oil supply affects production costs, the purchasing power of consumers as well as investment and could lead to social conflict. The scarcity of energy retards industrialisation and negatively impacts competitiveness (Calvacanti, 2011). An example of the consequences of energy scarcity was the fuel shortages in Malawi in 2012, when industrial productivity stagnated as a result of the long fuel queues (Chapter 1, section 1.2). A more dramatic example is mentioned by Robinson (2009) when the Malawi fuel storage tank in Mozambique was bombed during that country's civil war prompting the airlifting of fuel supplies from South Africa, a clear burden on the economy. One solution suggested by Nkomo (2009) is to widen the diversity of the sources of energy to replace in part the lost supply of oil. Widening diversity of supply involves "diversifying fuel types" (Nkomo, 2009, p.22). This echoes Palacio (2000, p.1) who says the key word is "diversification" of energy resources in energy supply management. As more types of fuel become available to compliment or replace fossil fuels, it becomes progressively easier to meet energy demand. A strengthening of the renewable energy sector offers a pathway to energy security by offering alternative fuels to fossils. An example by Balat (2011) is bio-ethanol, a renewable substitute fuel for petrol. Bio-ethanol has advantages over petrol because it is renewable, biodegradable, non-toxic, and essentially free of sulfur and aromatics (benzene type chemicals).

The maintenance of strategic oil reserves, apart from fuel type diversification and energy source diversification, is another method for circumventing disruptions to oil supplies. According to Nkomo (2009), storage of crude versus petroleum products offers advantages such as lower storage costs, easier quality maintenance and flexibility in producing the required product. This presupposes the importing country has the appropriate refining capability. The protection offered by such reserves is to the extent of the stockpile quantities held..As already mentioned, the finite oil resource is motivating the search for renewable energy sources specifically biofuels. The following discussion on peak oil explains the limited oil resource and its implications.

2.4.2 Peak oil

In 1956, Marion King Hubbert presented a paper to the American Petroleum Institute in which he postulated that oil production in the USA would peak in 1970. In his words, "the date of culmination in this case should be approximately 1970" (Hubbert, 1956, p.35). The basis was that the quantity of fossil fuels available on earth took a long time to form and although the natural formation was continuing, the rate of formation would not match the rate at which the fuels are being exploited. In his job at Shell oil as a geologist, he noted that oil discoveries graphed over time tended to follow a bell shape curve (Crooks, 2013).

Figure 2.4.2: HUBBERT CURVE



Source: Crooks (2013)

He supposed that the rate of oil production would follow a similar curve, now known as the Hubbert Curve (Figure 2.4.2). The Hubbert curve in Figure 2.4.2 is used to predict the rate of production from an oil producing region containing many individual oil wells. The point at which the world's oil supplies go into irreversible decline is "peak oil" (Crooks, 2013). The top of the curve (Figure 2.4.2) is the "peak oil". Energy policy is not yet significantly affected by the "peak oil" debate partly because geologists do not agree on the actual peak oil year and partly due to the volatility of geopolitics in the oil producing countries which has affected oil extraction (Crooks, 2013; Nkomo, 2009; Balat, 2011). Sheehan *et al*. (1998, p.5) sums up the debate on peak oil year as follows "Regardless of whose perspective we choose to believe on the future of coal, oil, and natural gas, their supply is, ultimately, limited."

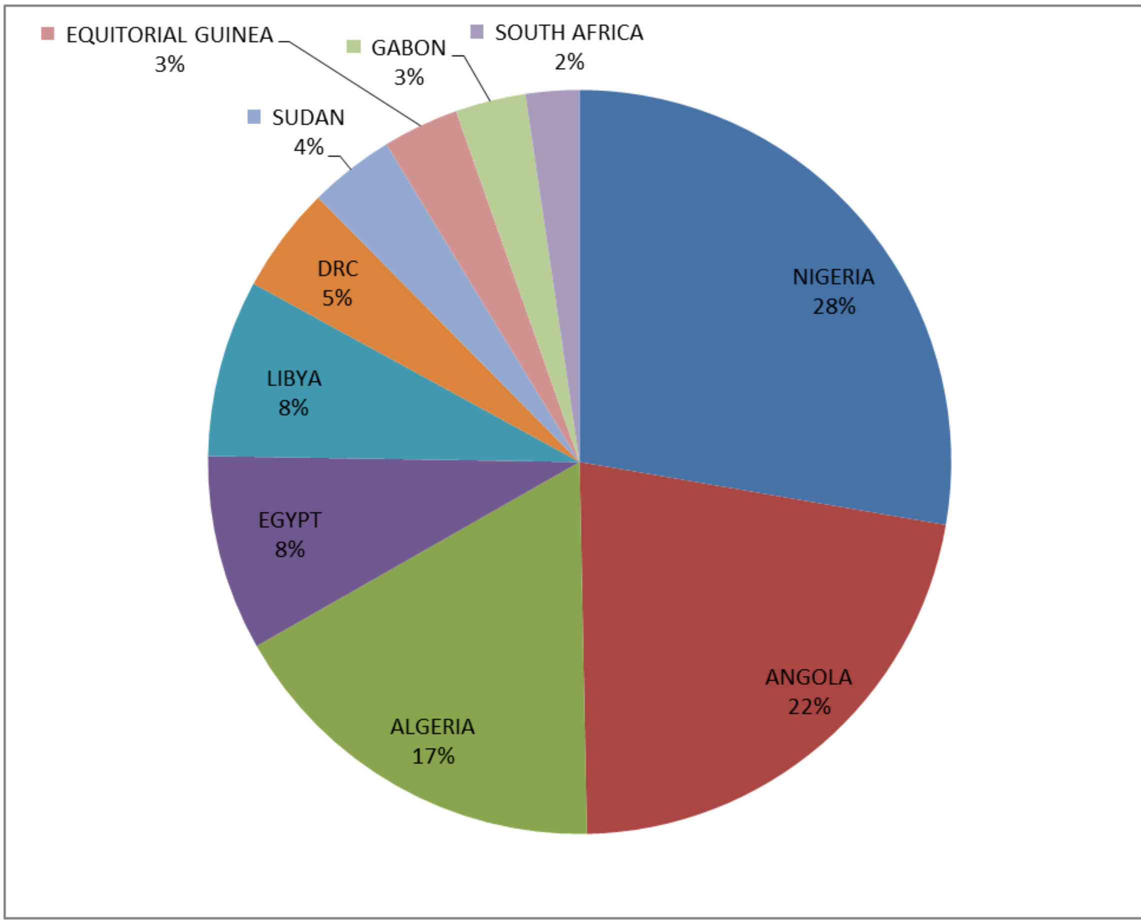
A concept called net energy or energy returned on energy invested ratio (EROEI) helps explain why alternative sources of energy must now be sought (Grubb, 2011). Cheap oil has in the recent past generations helped to accelerate the growth of many economies. Previously a barrel of oil used in exploration and drilling of oil would yield a hundred barrels. Now as the more accessible oil has already been exploited it takes more barrels to access the oil in the earth. The EROEI ratio is much lower and continues to drop. According to Grubb (2011) many alternative energy sources including many industrial methods of producing biodiesel and ethanol have EROEI ratios of less than one. This means more attention and effort should be paid to the production of alternative energy including biofuels as opposed to exploration and drilling for fossils which are now more difficult to access. The higher EROEI for ethanol means less effort needs to be expended in its development than in searching for fossils which are becoming more expensive to extract as "peak oil" is approached (Hubbert, 1956). Developing a framework for promoting sustainable ethanol production is therefore justified.

In this section the researcher found that oil is dominant in the energy mix. In the next section the dominance of oil in the energy mix and the interest in biofuels in Africa was reviewed.

2.5 African energy scenario

The continent of Africa has large oil reserves which remain untapped due to many reasons among them political and development agendas (Chapter 1, section 1.4). The continent is believed to contain about ten percent (10%) of the world's oil reserves (Ghazvinian, 2007). The interest by the developed countries in African oil is driven by three factors that have nothing to do with abundance. These are the quality of the oil, "light and sweet" meaning that it is cheaper to refine because it has low sulfur and is of low viscosity. Secondly the African location means shipping lanes to Europe and the USA do not require pipelines thus lowering transport costs significantly. Thirdly, apart from Nigeria, oil producing countries in Africa are not members of the oil producing and exporting countries (OPEC) and this tends to make African oil cheaper (Ghazvinian, 2007).

Figure 2.5: African Oil Production – 2015



Source: African Vault (2015)

Figure 2.5 profiles the African oil producing countries with Nigeria being the largest producer at twenty eight percent (28%) followed by Angola and Algeria, at twenty two percent (22%) and seventeen percent (17%) respectively. Malawi is not yet an oil producing country (Kambatata, 2012).

Links between energy, environment and development goals are more and more brought into prominence by growing concerns over climate change impacts and the high dependence on fossil fuels (Seebaluck and Johnson, 2012). This has brought about intense interest in bioenergy from sugarcane and other crops in

Africa. According to Nji and Cameroon (2006), soaring world crude oil prices are pushing non-oil producing African countries to seek ways of lessening their dependence on oil. Some countries have already switched to alternative sources "including biofuels" (Nji and Cameroon, 2006, p.17). The Table 2.5 represents the declared biofuels aspirations of countries on the African continent from one equipment supplier's view point (Chaudhari, 2008). As pointed out in the notes in Table 2.5, not all countries have achieved their declared intentions. Diesel blending with ethanol has for the most part not commenced.

Table 2.5: African Biofuel Plans - 2008

COUNTRY	**MILLIONS LITRES /YEAR ETHANOL(E) + BIODIESEL(B)**	**% blend with ethanol**	**% blend with diesel**
ZIMBABWE	**217**	**E10**	**B10**
MOZAMBIQUE*	**57**	**E10**	**B10**
TANZANIA*	**161**	**E10**	**B10**
KENYA	**207**	**E10**	**B10**
MALAWI	**47**	**E20**	**B10**
ZAMBIA*	**43**	**E10**	**B5**
GHANA	**116**	**E5**	**B5**
BOTSWANA*	**43**	**E5**	**B5**
SOUTH AFRICA*	**465**	**E2**	**B2**
TOTAL	**1,356**		
COUNTRIES MARKED*	**ARE WORK IN PROGRESS.**	**yellow not done**	

Source: Chaudhari (2008)

According to Batidzirai and Johnson (2012), Malawi is also the only African country that has consistently used liquid biofuels for transport for an extended period – since 1982, with blends ranging from 10% to 24%. Other countries in the region, such as Kenya and Zimbabwe, have used ethanol blends over shorter periods or at lower scales (Batidzirai and Johnson 2012). The high commercial value of sugar and ethanol has brought considerable socio-economic benefits to both small farmers and estate workers. Blending of straight vegetable oil (SVO) with diesel and with paraffin is now also under way in Malawi; the oil is produced by some 25,000 small farmers that plant Jatropha curcas as hedge rows around their farms.

According to Mitchell (2010), Africa's vantage point is unique in relation to biofuels production and biofuel crop potential. The natural resources on the continent present advantages in terms of domestic and export markets. Exports to the EU, for example, will benefit from high energy prices and consumption mandates which are expected to increase the global demand for liquid biofuels (ethanol and biodiesel).

In this section the researcher has noted that there is a lot of potential for exploiting oil in Africa and the conditions are favourable. The review has further shown that some African countries are transitioning to using biofuels. In the next section, the review focuses on Malawi.

2.6 The Malawi energy context

The Malawi liquid fuels portfolio is dominated by fossil fuels which includes: petrol, diesel, aviation gas and paraffin (Department of Energy Affairs, 2003). A reading of the National Energy Policy (2003) reveals that the policy does not integrate existing or emerging biofuels in the liquid fuels portfolio.

Table 2.6 Imported fuel in Malawi from 2004 to 2016

	MALAWI FUEL IMPORT STATISTICS			
	Fuel Imports / Sales ('000s of Litres			
Year	**Diesel**	**Petrol**	**Paraffin**	**Total**
2004	142,629	89,258	20,513	252,400
2005	151,714	82,377	21,839	255,930
2006	164,135	88,349	17,800	270,284
2007	172,470	92,143	16,523	281,136
2008	199,245	103,004	17,957	320,206
2009	198,394	106,376	13,452	318,222
2010	207,300	110,100	11,500	328,900
2011	163,666	92,640	8,089	264,395
2012	89,192	43,124	0	132,316
2013	188,742	108,852	0	297,594
2014	179,622	112,068	1,568	293,258
2015	133,104	170,456	506	304,066
2016	166,190	190,395	852	357,437

Source: MERA (2017)

The intended direction of the policy is focused on petroleum products and mentions biofuels in a cursory manner with no clear direction. Ethanol has been part of the liquid fuels portfolio since 1982 although the National Energy Policy was only promulgated in 2003 (Jumbe et al., 2007). Table 2.6 shows the fuel imported in Malawi for the period 2004 to 2016 while Table 2.6.1 shows the production of ethanol for the same period.

The Table 2.6.1 is a record of ethanol production from 2004 onwards, the year the second ethanol production facility at PressCane came on stream. The annual total ethanol production of the two companies has over the years not matched the 20% blending mandate (see statement of the problem Chapter 1 section 1.9.1). It is important to note that the ethanol production record required by and available at MERA is only that of the fuel ethanol produced. This exacerbates the gap between the 20% mandate requirement and the actual available ethanol fuel because some volumes of ethanol go into beverages and pharmaceuticals (Chapter 1, section 1.6 and Figure 1.6).

Table 2.6.1.Etahnol production from 2004 to 2015

	PRESSCANE LIMITED			ETHANOL COMPANY LIMITED				
Year	AA	RS	Year Totals	AA	RA	ENA	Year Totals	Year Alcohol Prod Totals
2004	4,549,415	-	4,549,415	10,770,250	1,152,624	599,695	12,522,569	17,071,984
2005	7,321,365	577,987	7,899,352	3,783,127	3,397,821	718,885	7,899,833	15,799,185
2006	6,959,617	789,484	7,749,101	2,596,530	2,909,098	1,022,492	6,528,120	14,277,221
2007	6,258,973	2,029,463	8,288,436	2,727,768	2,735,382	1,039,328	6,502,478	14,790,914
2008	7,073,981	5,521,070	12,595,051	765,095	3,212,023	1,327,684	5,304,802	17,899,853
2009	4,491,932	4,671,882	9,163,814	1,997,886	814,041	5,034,774	7,846,701	17,010,515
2010	6,921,747	3,296,249	10,217,996	2,106,709	866,061	5,397,732	8,370,502	18,588,498
2011	9,962,591	865,272	10,827,863	1,760,576	296,180	6,793,255	8,850,011	19,677,874
2012	10,152,369	706,113	10,858,482	2,877,922	144,914	5,071,454	8,094,290	18,952,772
2013	9,806,757	678,212	10,484,969	3,133,948	195,815	5,570,573	8,900,336	19,385,305
2014	11,780,945	668,694	12,449,639	2,858,814	90,681	5,751,353	8,700,848	21,150,487
2015	14,671,560	1,371,202	16,042,762	3,394,034	91,031	7,219,221	10,704,286	26,747,048
Total	99,951,252	21,175,629	121,126,881	38,772,659	15,905,671	45,546,446	100,224,776	221,351,657

Source: ETHCO & PressCane Ltd, 2015 Board Packs

The preceding section examined the trends in oil imports and established that oil dominates. The total yield of ethanol from both ETHCO and PRESSCANE does not match the demand for blending at 20% ethanol and 80% petrol. This shows some gap. The objective of this study is to establish the causes of these gaps. In the next section, the energy policy in Malawi is discussed.

2.7 The Malawi Energy Policy

The energy policy was promulgated in 2003. The promulgation followed a participatory approach during which key stakeholders were consulted and participated in the process. The energy policy in Malawi has some gaps which are highlighted in the paragraphs that follow.

The National Energy Policy (NEP) as already stated mentions ethanol as part of the liquid fuels portfolio as follows:

"Malawi imports 97% of its refined petroleum, the balance is contributed by locally produced ethanol, sold directly to the oil companies for blending with petrol on a maximum 20:80 ratio of ethanol-petrol ……nearly 7% of the total liquid fuels market". (Department of Energy Affairs, 2003, p.73).

Since the promulgation of the energy policy, changes, in the liquid fuels industry have presented opportunities for ethanol to occupy a more significant place in the liquid fuels portfolio. An example of the changes is mandatory blending of ethanol and petrol (2009 Liquid Fuels and Gas Regulations).

The vision of the energy policy as noted already states the need for more secure supplies of petroleum products (Chapter 1, section 1.7). the policy focuses on petroleum products and does not recognize ethanol in the liquid fuels portfolio. To date no investment in pipelines has been made and a new government parastatal, National Oil Company of Malawi (NOCMA) has been set up to address the storage issues nearly ten years after the policy was published (Khanje, 2012). In the discussion the researcher had with the NOCMA management, it transpired that there are no plans to store ethanol. Oil exploration has begun recently near the northern border with Tanzania and has ignited an international border dispute with Tanzania and raised the specter of dead fish (Kambatata, 2012).

It is paradoxical that biofuels are not mentioned in the policy considering that ethanol has been part of the liquid fuels portfolio since 1982 and the policy was only made in 2003 (Chapter 1, section 1.6; Chirembo, 2012). However, inadequate blending of ethanol and petrol in the ratio of 20% ethanol and 80% petrol is mentioned as one cause of inefficiency in the liquid fuels supply (Department of Energy Affairs, 2003, p.28, p.30, p.73). The explanation for this anomaly may emerge as the research progresses.

The policy has some glaring gaps in terms of commitment to promote the production and use of ethanol. The gaps are highlighted in the sections that follow.

2.7.1 Failure of the policy to recognise biofuels solution

Malawi has suffered from serious fossil fuel shortages over the years for reasons ranging from conflict in neighbouring countries to foreign exchange shortages (Robinson, 2009; Lea and Hanmer 2009; Kambatata, 2012). The responses by government have been largely directed at finding more resources to procure more fossil fuels. Recognizing biofuels as a solution would have a variety of positive implications such as foreign exchange saving and enhanced energy security. Section 2.12 highlights the advantages of ethanol.

2.7.2 No biofuels strategy in the energy policy.

The role of biofuels is fully discussed in section 2.10. The efforts of government in achieving an optimal energy portfolio (mix) particularly in liquid fuels are not productive due to the biofuels potential not fully being harnessed. This has recently been brought into focus whenever a fuel shortage occurs, by government officials lamenting over inadequate ethanol volumes in Malawi (Kambatata, 2012). As noted before the energy policy is focused on “getting cheaper guaranteed supplies of petroleum products” (Department of Energy Affairs, 2003, p.21).

The GBI has as its stated aim, to increase sugar production (section 2.3.4). Power generation from bagasse and ethanol production is not included in the scope. The GBI representative, in several meetings with the researcher , stated that government had not planned for an ethanol plant to be part of this initiative. The Chairman of GBI at the time concurred but welcomed the idea of the private sector contributing by building an ethanol plant (OPC/GBI, 2014).

2.7.3 No diesel blending strategy.

The possibility of blending diesel with ethanol or any other biofuel is not enshrined in the energy policy. This is another missed opportunity by government to relieve the foreign exchange burden, among other things, by using existing biofuels such as ethanol. Literature shows that diesel blending with biofuels particularly ethanol is possible (Chaudhari, 2008). Sweden is a successful case of diesel blending with ethanol (Löfvenberg, 2007). The demonstrations, in several countries including Malawi, with both hydrous (diesohol) and anhydrous ethanol blends (ED-diesel) date back to 1993 and have shown that various diesel ethanol blends can be used in diesel engines without any engine modifications (Löfvenberg, 2007, p.7). The other major benefit is that no changes are required in existing transport and distribution infrastructure including filling stations. Increasing ethanol volumes with the possibility of blending diesel with ethanol is an opportunity to be retrieved for Malawi.

2.7.4 Storage targeting petroleum only.

The energy policy includes petroleum fuel “storage facilities” as a way of dealing with inadequate fuel volumes (Department of Energy Affairs, 2003, p.21). The quantum of this investment could be significantly reduced by increasing and including ethanol in the liquid fuel portfolio. The actual implementation of the storage aspect of the policy commenced ten years after the energy policy was promulgated.

2.7.5 No oil pipeline to date.

Investment in oil pipelines is mentioned in the energy policy together with storage in the context of securing liquid fuel energy security. As with tank storage, nothing has actually been done in this respect. This investment could be avoided completely if ethanol volumes were increased significantly, given that ethanol is the only biofuel officially in use. The advantages of biofuels in general and ethanol in particular are discussed in section 2.19.1.

2.7.6 No oil exploration strategy in the energy policy.

Oil exploration is envisaged by the energy policy as a pathway to energy security. Efforts in this direction have recently begun and have raised national territorial concerns with neighbouring countries (Kambatata, 2012). On the other hand, if ethanol volumes were significantly increased the search for contentious petroleum oil sources may not be necessary.

2.7.7 Petroleum products transport by road tankers versus rail.

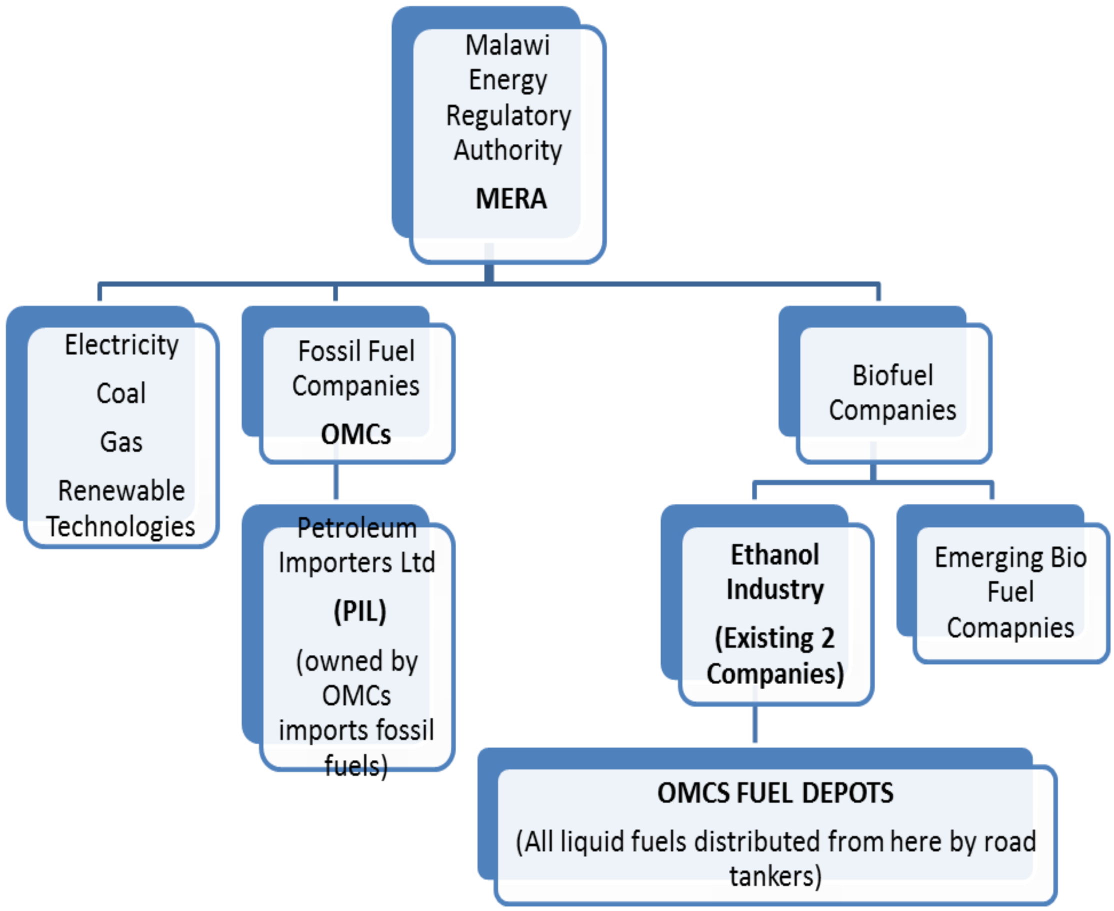
Consistent petrol blending with ethanol at the mandated twenty percent (20%) would reduce the number of road tankers required to bring in imported fossil fuel (Ziba, 2010). Transport costs in Malawi account for an estimated fourteen percent (14%) of total product costs, compared to the world average of six percent (6%) (UNCTAD, 2011). Introducing the use of ethanol driven vehicles (EDVs) would cause a significant increase in the use and production of ethanol and further reduce the need for importation of petroleum fuels. The savings would then be redirected to other sectors such as health and education.

In this section, the researcher interrogated the energy policy in Malawi and found that there are glaring gaps in terms of commitment and action to promote the production and use of ethanol.

2.8 The Malawi Energy Regulatory Authority (MERA)

The liquid fuel industry in Malawi is regulated by the Malawi Energy Regulatory Authority (MERA) as shown in Figure 2.8 which was established as the Energy Sector Wide Regulator (Energy Regulatory Act No. 20 of 2004).

Figure 2.8 Malawi Energy Regulation Hierarchy



Source: Author

MERA began operating in January 2008 (MERA, 2008). Two MERA consultative workshops attended by forty six participants, including the author, in April and May 2008 reviewed the first four year strategic plan (MERA, 2008, p.43). It is worth noting that the PESTEL (Political, Economic, Social, Technological, Environmental and Legal) and SWOT (Strengths, Weaknesses, Opportunities and Threats) analyses conducted by MERA were directed at fossil fuels as the following selected quotations in BOX 1 demonstrate:

BOX 1

> *"**3.5.1 Problem Statement***
>
> *Malawi does not have secure and reliable supplies of fuel because of lack of storage capacity, poor transportation system and other logistical and administrative problems in the supply chain. Consequently, the country suffers frequent interruptions and shortages in fuel supplies.*
>
> ***3.5.2 Goal***
>
> *To create an environment which mitigates interruptions and consequent scarcity of petrol, diesel, paraffin and jet fuel supply into the country.*
>
> ***3.5.3 Objective 1: To promote minimum storage capacities requirement for petrol, diesel, paraffin and jet fuels***
>
> *MERA shall promote the storage capacity of thirty (30) days for any fuel marketing company before replenishing of stock to cushion interruptions in the supply chain.*
>
> *MERA shall also introduce a storage levy to incentivize the investment in the storage of fuel in the supply chain."* (MERA, 2008, p.20)

Source: MERA (2008)

The PESTEL and SWOT analysis comments emanating from the MERA consultative workshops are at variance with the energy policy in terms of recognizing biofuels, specifically ethanol. Further the thirty year legacy of blending petrol with ethanol already described (section 2.6) adds to the puzzle. All energy activities fall under the ambit of MERA. The relevant legislation includes the following:

a) The Energy Regulation Act 2004;
b) The Electricity Act 2004;
c) The Rural Electrification Act 2004; and
d) The Liquid Fuels and Gas (Production and Supply) Act 2004.

There are four major oil marketing companies (OMCs), namely PUMA (formerly BP), TOTAL, ENGEN, and PETRODA. These formed a company, Petroleum Importers Limited (PIL) in 1999 to handle oil import logistics on behalf of its members (Namangale, 2012).

2.9 Liquid fuel importers and logistics

Petroleum Importers Limited (PIL) a private company was formed for the purpose of importing fuel for the OMCs as already mentioned (Section 2.8; Khanje, 2012). Fuel importation until then was largely done by a government parastatal called the Petroleum Control Commission (PCC) from whom the oil marketing companies would purchase their supplies to distribute in Malawi. According to Khanje (2012) PCC was a regulator that had been forced into fuel importation after the oil marketing companies had given up importation in 1994 following the devaluation of the Malawi Kwacha. Except for coal, all the fossil based fuels are imported through the ports of Dar-es-Salaam in Tanzania, Beira in Mozambique and Durban in South Africa. The fuels are used for domestic purposes (liquefied petroleum gas [LPG], paraffin), road and marine transport (petrol, Avgas, diesel), air transport (Jet A1, kerosene), industries (diesel, coal, LPG), electricity generation (diesel, petrol) and irrigation (diesel, petrol) (Environmental Affairs, 2002).

Another government parastatal company, the National Oil Company of Malawi (NOCMA), was formed in 2011 for strategic fuel storage as a means to mitigate fuel shortages (Khanje, 2012). The storage facilities formerly operated by PCC as transit points for fuel coming into Malawi from Dar es Salaam are now part of NOCMA. The storage facilities were initially meant for commercial importers who did not have their own storage. According to a NOCMA official, interviewed by the author, at inception there was no ethanol storage considered, even though the liquid fuel portfolio includes ethanol by law. This represents another strategic gap in the management of liquid fuels in Malawi.

In this section, the researcher reviewed literature focusing on importing petroleum products and the logistics involved. The role of biofuels in addressing energy challenges is further discussed in the next section.

2.10 Role of biofuels in addressing energy challenges

Biofuels are renewable energy sources that are produced from recently living organisms or their byproducts (Balat, 2008; Biofuelindonesia, 2007). The term is most commonly used to refer to liquid biofuels, bioethanol and biodiesel (Balat, 2008). They are fuels developed from specifically grown agricultural products. In the case of bioethanol, it is agricultural products containing sugar, starch or cellulose (Larsson, 2006). Mitchell (2010, p.113) quotes Article 2 of the EU energy directive where "biofuels means liquid or gaseous fuel used for transport and produced from biomass". Biofuels can be divided into three categories (Chevron, 2012):

a) First-generation biofuels are made largely from edible sugars and starches.

b) Second-generation biofuels (also called advanced biofuels) are made from nonedible plant materials.

c) Third-generation biofuels are made from algae and other microbes.

It must be noted that limited commercial production facilities have been established for third generation biofuels as they are still being researched (European Parliament Council, 2009). High energy prices and consumption mandates are expected to increase the global demand for liquid biofuels (ethanol and biodiesel) (Mitchell, 2010). The Figure 2.10 illustrates the volatile and often rising global oil prices which have pushed up energy costs.

Figure 2.10 Rising global oil prices

Source: West Texas Intermediate (2017)

In this section, the role of biofuels in addressing challenges in the energy sector was reviewed. The review shows that biofuels are an alternative energy. In the next section, the contribution of biofuels to future prospects is discussed.

2.11 Biofuels contributing to future prospects

According to Berg (2013), about 5% of the ethanol produced in the world is actually a petroleum product. Synthetic ethanol is chemically identical to bioethanol with the same chemical representation of C_2H_5OH. The term bioethanol is meant to emphasize that the source is agricultural given that synthetic ethanol exists and would not be considered a biofuel. Although petroleum (fossil) fuels are depleting (Hubbert, 1956; Grubb, 2011), the synthetic ethanol does not form part of the solution to dwindling fossil fuel sources.

Before World War II, biofuels were seen as providing an alternative to imported oil in western countries. A testament of this is the Ford Model T (1903 to 1926) designed by Henry Ford to run completely on ethanol (Biofuelindonesia, 2007). After the war, cheap Middle Eastern oil lessened interest in biofuels. In the 20th century petroleum based fuels became the dominant source of energy for transportation needs (Demibras and Balat, 2006). This has continued in the beginning of the 21st century with almost all vehicles running on gasoline, diesel or natural gas (Loppacher and Kerr, 2005). Rising oil prices, fears over the potential oil peak, global warming, and unstable politics in the Middle East are fueling renewed interest in biofuels (Balat, 2008).

In the 1970's there was an oil embargo by the oil producing and exporting countries (OPEC). This revived the use of ethanol as a fuel in the world and Brazil became a leader in the use of ethanol as a fuel in vehicles (Er, 2011). According to Meher et al.,(2006) cited by Balat (2008), rising oil prices concerns over the potential oil peak, global warming, and instability in the Middle East is refocusing interest in biofuels. This interest in biofuels represents a significant solution in meeting future energy requirements. Calvacanti (2011, p.2) argues that there is huge potential "in the sugar industry for the production of ethanol as an alternative to fossil fuels". Fumo (p.9, 2009), says "ethanol from sugarcane is by far the cheapest fuel to produce, because there is no need to make a transformation from carbohydrates to sugar, which is afterwards fermented to alcohol. According to Xavier (2007), the following are the advantages of making ethanol from sugarcane:

a) Ethanol produced from sugar consumes less nonrenewable fuel in comparison with corn;

b) Sugarcane has a highly favourable energetic balance, compared with other ethanol sources (sweet beet, corn, sweet sorghum, etc.);

c) Sugarcane‗s productivity is roughly twice that of corn-based ethanol (liter per hectare), when there is favorable climate;

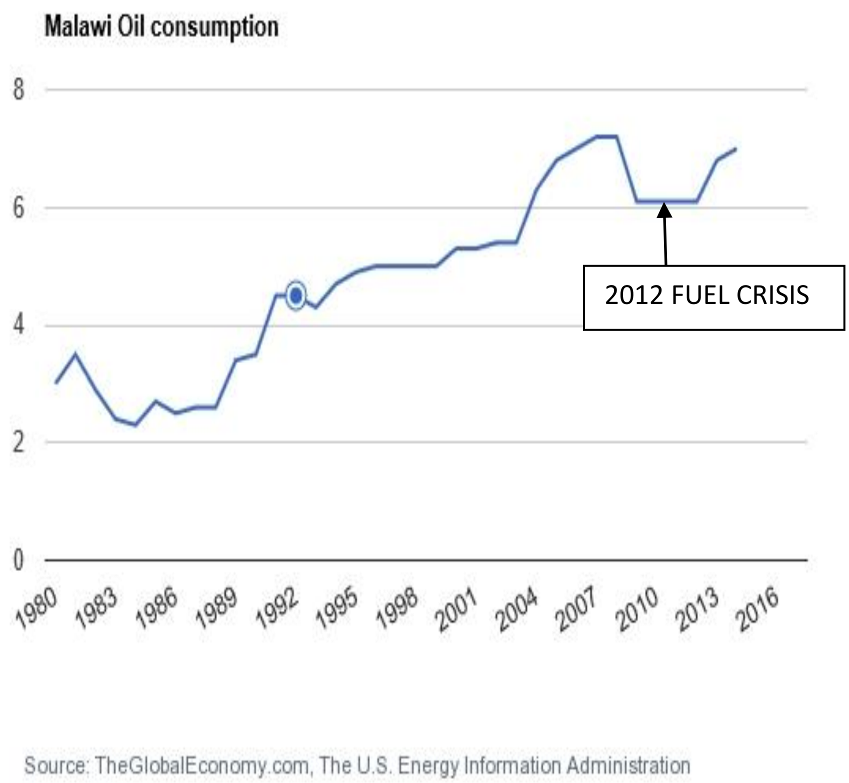
d) Apart from ethanol, sugar and electricity are other by products.

In this section, the contribution of biofuels to future prospects was investigated. It was established that ethanol has a lot to contribute to future prospects. In the next section the role of biofuels in Malawi is interrogated.

2.12 Role of biofuels in Malawi

The earliest fuel shortages in Malawi were in 1979 due to sabotage by South Africa on the Mozambique fuel storage facility in Munhava during the Mozambique civil war (Robinson, 2009). On the world scene that year 1979, the Iranian revolution had toppled the Shah of Iran causing a world oil crisis that eventually found its way to Malawi in 1982, triggering fuel queues among other things (Lea and Hanmer, 2009). Figure 2.12 illustrates graphically the sharp decline of fuel imports into Malawi in the years 1982 to 1984. The response to the crisis was a directive by President Banda that an ethanol company should be built (Jumbe *et al.,* 2007). The blending of ethanol and petrol which began in 1982 only became mandatory in 2010 (Extra Ordinary Gazette, 31st December, 2010).

Figure 2.12 Malawi petroleum consumption 1980 to 2016

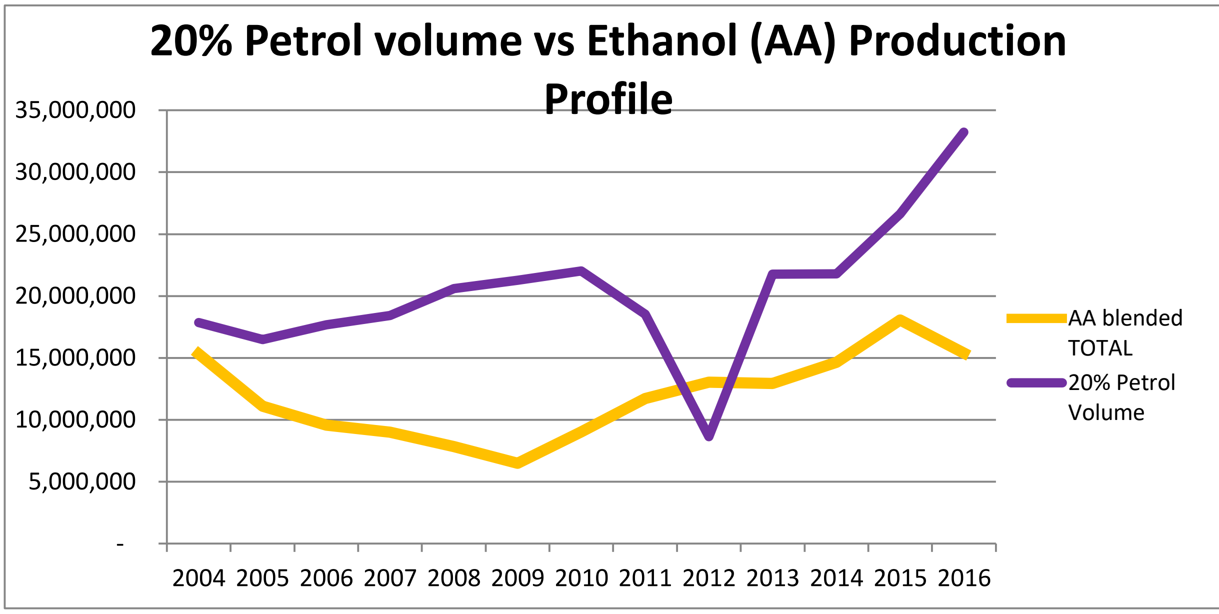


Source: TheGlobalEconomy.com (2017)

The fuel shortages in 2012 in Malawi have seen interest in ethanol as a possible solution to energy security soaring (Kambatata, 2012; NCST, 2011). Figure 2.12 shows the 2012 fuel crisis when petroleum imports sharply declined. The ethanol driven vehicle project which started in 2006 following a cabinet directive in 2004 was concluded in 2011 with the already known result that cars can run on ethanol (NCST, 2011, p.3). Considering that from 1982 Malawi petrol was blended with ethanol it is the author's view that this was an unnecessary exercise. Indeed at the initial stakeholder's conference this view was strongly expressed to government officials to no avail.

Ethanol volume in the liquid fuel portfolio for Malawi remains small compared to the fossil fuel volume (Figure 2.12.1). The sharp drop (convergence of the purple and yellow lines in Figure 2.12.1) in petrol volumes from 2010 to 2012 represents the period when there were acute fossil fuel shortages in Malawi (Kambatata, 2012). However when fossil fuel imports normalised the gap between the required blend ethanol (AA) volume and petrol continued to widen (Chapter 1, section 1.9.1).

Figure 2.12.1: Acute fossil fuel shortages period 2010 to 2012



Source: Author's analysis

In the following sections the objectives of the research are examined in the light of the literature reviewed, to glean lessons and side-step similar inconsistencies while developing a robust framework.

2.13 Objective a): Determine the level of awareness on biofuel policy and strategy.

The researcher reviewed literature focused on the first objective which is "to determine the level of awareness of biofuels policy and strategy". Summarised in the paragraphs that follow are the findings from this review.

According to Mitchell (2010), it is important to embark on an awareness campaign on the advantages of biofuels. He argues that the acceptance of the use of biofuels by the public is necessary. Government policies on biofuels such as ethanol need to be consistent over time. The reasons include fostering private sector confidence and reducing investor uncertainty. Building strong public commitment to biofuels is necessary to overcome resistance and opposition from existing fuel suppliers. Consumers support must be secured to achieve a successful biofuels regime. Xavier (2007, p.9) illustrates the point of consumer awareness and the impact that it has on policy and strategy as follows:

“As ethanol provides fewer miles per gallon than gasoline, Brazilian drivers know that ethanol is price-competitive only when it costs no more than 70 percent of the price of gasoline. In March 2006, the blending ratio was reduced from 25 percent to 20 percent after ethanol prices soared to all-time highs. Brazilian drivers stopped using pure ethanol as the price reached $0.90, about 85 percent of the price of gasoline”.

Johnson and Silveira (2014), say that the 1986 Brazilian National Motor Vehicles Emissions Control programme using ethanol to address pollution, had many objectives, among them were “to sensitise the population regarding air pollution issues”. The program is credited with significant pollution reductions from vehicles for the period prior to 1980 when petrol did not have a prescribed ethanol blend ratio. According to Mitchell (2010), a ninety six percent (96%) reduction of carbon monoxide, hydrocarbons, nitrogen oxide (NOx), and total aldehydes had been achieved by 2008. The Brazilian bioethanol programme is the largest and most successful in the world (Almeida, 2007). This achievement is partly due to the awareness of the population regarding the intentions of the ethanol policy and strategy. However, there were drawbacks along the way such as concerns that the demand for sugar for bioethanol production was taking up land for food. According to Dunmore (2011), the controversy centers on indirect land use change (ILUC), a relatively new concept that the rapid expansion of biofuel production in recent years is driving up the overall demand for agricultural land. According to Barber et al. (2008) there is little information available in the area of ILUC and “what has been published is conflicting and based on limited data and a large number of assumptions” (p.6). This demonstrates the criticality of complete information to enhance awareness of biofuel policy and strategy for the success of a biofuel regime. In the case of Brazil, ethanol policy and strategy awareness included the final consumers apart from the policy makers.

The International Energy Agency (2008), says policy makers in Asia have long-run concerns over energy security and pollution problems which are critically important. According to Shinoj et al. (2011), developing renewable energy will mitigate the depletion of crude oil and its impact on the environment. According to O’Kray and Wu (2010), the awareness of the negative consequences of fossil oil dependence, such as environmental pollution, rising oil prices, depleting oil reserves and other problems are bringing to the fore the search for renewable energy alternatives to oil. Biofuels such as ethanol in China therefore present a unique opportunity to solve the energy dilemma. Gonsalves (2006) says, awareness of this imperative has made China one of the largest bioethanol and sugar producers and consumer coming behind only Brazil and the United States of America. This positive outcome has for decades been stifled by food security concerns but policy makers embedded the biofuel policy in the five year national development plan to ensure the success of ethanol production and use (O'Kray and Wu, 2010). In the case of China, ethanol policy and strategy awareness were the preserve of policy makers.

The EU biofuels directive 2009/28/EC article 80, says biofuel advantages must be highlighted and clearly linked to the reduction of GHGs (European Parliament, Council, 2009). The directive goes further to propose the funding of an awareness campaign on second generation biofuels sources such as cereals and forest residues to foresters and farmers with the express intention of promoting the use of biofuels in the EU (article 1, 86). The link of biofuel use to climate change mitigation is to be highlighted to stimulate the demand for biofuels along with economic activity and job creation opportunities.

The EU biofuels policy has biofuel use awareness as a major hallmark. The EU biofuel strategy has three objectives,

a. To promote biofuels in the EU and developing countries.
b. To prepare for the large scale use of biofuels.
c. To increase cooperation with developing countries in the sustainable production of biofuels.

These objectives point to awareness as being a crucial ingredient in crafting biofuel policy and implementing biofuel strategy not only in the EU but in other countries as well.

2.13.1 Analysis.

For a successful biofuels regime it is important that the extant biofuel policy and strategy be known by all the participants. The Brazil model, considered the best world over has a comprehensive level of awareness. The policy makers, sugar cane producers, ethanol manufacturers as well as the car drivers, the end users of ethanol, are able to react to policy changes. The clear contrast with the Malawi situation is that there is no biofuel policy (Jumbe *et al.*, 2007). Policy makers are aware of the blend mandate although comments by some high level public figures in times of fossil fuel shortages demonstrate that they are not aware of the state of biofuels, specifically ethanol, in Malawi (Sundu, 2012). The blend mandate represents a biofuels strategy which is also not fully understood, hence the gaps already mentioned (section 2.7).

According to Colares (2008), the National Alcohol Program ("Proálcool"), Brazil's first biofuels program, was the country's response to the oil price spikes associated with the 1973 oil crisis. Proálcool essentially focused on the production of ethanol from the distillation of sugar extracted from sugar cane, a staple crop in Brazilian agriculture. The program, signed into law by President Ernesto Geisel on November 14, 1975, effectively created a nationwide ethanol production chain based on a system of government subsidies and tax rebates to sugar cane producers and distilleries (Colares, 2008). According to O'Kray and Wu (2010), the Chinese central government decided in 1986 to produce ethanol from wheat in Henan province due to a surplus wheat harvest. On the other hand the government of India mandated ethanol blending with petrol in 2003 with a view to enhance rural development (Government of India, 2002). Shinoj et al. (2011), says the Indian National Policy on biofuels deliberately sets out to empower rural populations as a development strategy. Sugarcane in India is a smallholder crop and cane and sugar prices are government controlled as part of the biofuels strategy (Chipukunya and Kacelenga, 2011). The European Parliament Council (2009), biofuels directive (policy) insists on ensuring that awareness of policy and strategy are highlighted. The distinctive feature of the EU awareness campaign is the desire to include countries outside the EU.

In all the cases cited the biofuels policies or strategies did not originate from market dynamics. All were legislated first and all had strong state or government intervention in the beginning. The case of the USA biofuels program demonstrates how legislation is used to map future biofuels development (Tiffany, 2009). In the case of Malawi there was no legislation or documented policy or strategy, the president in 1982 ordered the establishment of the Ethanol Company Limited (ETHCO) in Dwangwa in the central region of Malawi, also in response to the 1973 oil embargo by the Oil Producing Countries (OPEC) (Jumbe et al., 2007). This begs the question of how much public awareness there was regarding ethanol production and use. Awareness of policy and strategy in the Brazil, China, India and EU cases was first present at the policy makers' level in the form of legislation. Cascading to the consumers' level was notably most successful in the case of Brazil and specifically legislated in the EU scenario. In contrast, awareness of the Malawi biofuel strategy, specifically ethanol, was limited to the producer (ETHCO) and the OMCs who had no choice but to blend. Fuel users were mostly unaware that they were buying a blend unlike in the Brazilian case. It is therefore a valid undertaking to "determine the level of awareness of biofuel policy and strategy". The research question is then framed as follows

What policies exist to coordinate bio-fuels and fossil fuels? (Chapter 1, section 1.10).

In this section, the review focused on the level of awareness about ethanol. In the next section the researcher focused on pathways for increasing ethanol production.

2.14 Objective b). Find pathways of increasing ethanol production

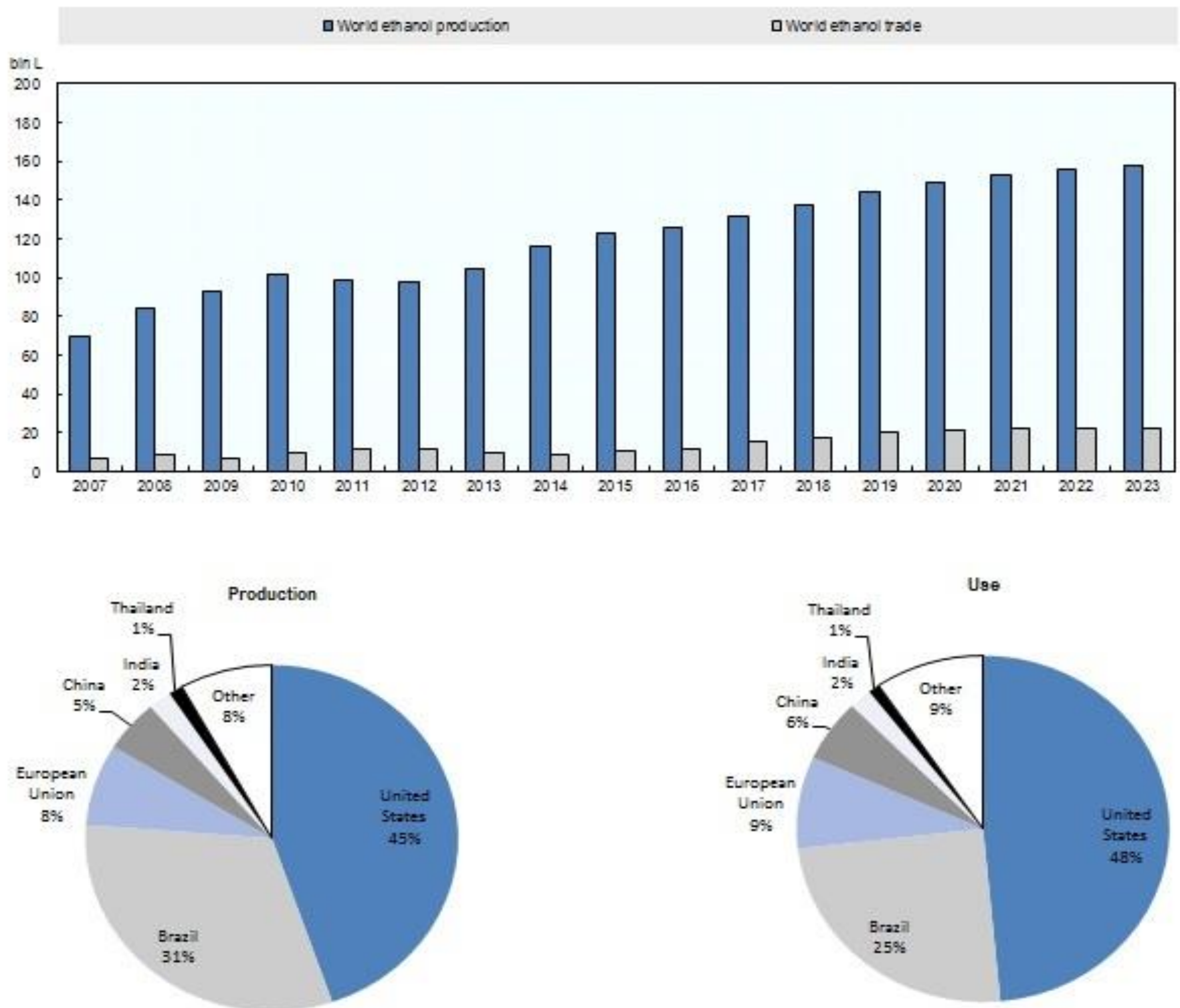
For the second objective, literature pertaining to pathways for increasing ethanol production was reviewed. The literature on Malawi biofuels is limited, as demonstrated by the absence of a biofuels policy. The researcher focused on documented successful or working biofuel programs or policies for various countries and regions that are aimed at increasing the production of ethanol. The selected countries are Brazil, USA, China, India and the EU. Gonsalves (2006) lists Brazil, United States of America, China and India as the leading biofuel producers in that order.

In the following section a description of the various country strategies are presented. The accounts have a mixture of pathways for increasing ethanol production and the reasons for doing so as well as policy and strategy.

2.14.1 Brazil's pathways for increasing ethanol production

Brazil is a global leader in the use of bioethanol as a fuel source (Er, 2011). The pie charts and graph in Figure 2.14.1 depict the leadership role of the USA and Brazil in the production and use of ethanol in the world.

Figure 2.14.1 WORLD ETHANOL PRODUCTION AND USE



Source: Voegele (2014)

Voegele (2014), says the two nations (USA and Brazil) account for over 75% of world ethanol production volumes as shown by the graph (histogram) in Figure 7. Er (2011), says sugar production for ethanol has been the chosen pathway for ethanol production in Brazil. Langevin (2010), says legislation in 1975, targeting the growth of sugarcane ethanol production, led to the establishment of the ProAlcool program which provided tax incentives, credits, and infrastructure to sugarcane and ethanol producers. This led to domestic ethanol production quadrupling between 1975 and 1985. The aim of ProAlcool was to reduce the dependence of Brazil on imported fossil fuels by using more ethanol in vehicles. ProAlcool was also a response to the impact fossil oil prices had on Brazil's balance of payments (Mitchell, 2010). This response had the effect of increasing sugar production for fuel (Barber *et al*., 2008).

According to Er (2011), the Brazilian bioethanol programme is the largest and most successful in the world but there were drawbacks along the way such as concerns that the demand for sugar for bioethanol production was taking up land for food. The debate revolves around indirect land use change (ILUC), where the rapid growth of biofuel production in recent years is assumed to increase the demand for agricultural land (Dunmore, 2011). According to Barber et al. (2008, p.6) there is little information available in the area of ILUC and "what has been published is conflicting and based on limited data and a large number of assumptions". McGrath (2013) agrees and points out that current research has not found any clear bias towards biofuel crops in the context of land acquisitions labeled 'land grabs'. Lendle and Schaus (2010, p.8) commenting on the Brazilian Cerrado (a highly biodiverse area) state that "it is believed that sugar cane expansion puts relatively low pressure on protected areas because it mainly takes place on former pasture land, but the impact on indirect land-use change is not yet fully understood". According to Goes et al., (2011), area under sugarcane has grown by 35% from 1940 to 2010 while sugarcane yields per hectare have grown by 43% from 40 tons per hectare (TCH) to 79TCH in the same period. Landell et al., (2010) quoted by Goes et al., (2011, p.3) claim that yields of 150TCH are achievable. The global average TCH is quoted at 70.2 by Pham (2014). This suggests that land requirements for sugarcane cultivation can be greatly reduced via the use of new high yielding sugarcane varieties.

Brazil's example leads the world (Hira and de Oliveira, 2009). These assertions are not universally accepted as shown by the divisions on biofuel benefits in the EU (Bourguignon, 2015). However, Brazil is a global reference point for a successful ethanol program. According to Xavier (2007), the Brazilian national alcohol program, PROALCOOL was both an energy security program and an agricultural price support program.

The next section looks at the case of the United States of America's ethanol program.

2.14.2 The United States pathways for increasing production of ethanol

The United States biofuels program is ranked highly (Demirbas and Balat, 2006). DOE (2014) says the United States energy endeavours will be mainly aimed at securing access to oil and reducing demand for energy while developing other sources. Other western nations may follow a similar energy agenda given the security instability around oil producer nations (Pippard, 2010).

According to Hoekman (2009), America has legislation aimed at increasing the usage of biofuels especially ethanol from corn. The reasons include energy security, diversity and sustainability as well as GHG reduction. Tiffany (2009, p.44) confirms that “the primary goal of using ethanol is the reduction of harmful and toxic emissions such as benzene”. The state of California is the leader in aggressively promoting biofuel use and has a goal of a twenty percent (20%) increase of renewables of total road transport fuels by 2020 and by thirty percent (30%) by 2030. The Energy Policy Act (2005) has many provisions including energy efficiency and conservation, modernization of energy infrastructure and promotion of both traditional and renewable alternatives. Koplow (2007) mentions a number of tax incentives a result of the EPA (2005) which targeted corn ethanol production as well as ethanol use such as volumetric excise tax credits, market price support, reductions in state motor fuel taxes, federal grants, demonstration projects, research and development grants, accelerated depreciation on assets and federal small producer tax credit among others. Susbsequently the Energy Independence and Security Act of 2007 was passed to specifically incentivise biofuels from cellulosic material, that is second generation biofuels (Hoekman, 2009). Ethanol producers who use cellulosic raw materials get higher tax breaks compared to those still using corn. The aim is to safeguard food crops from being used as energy crops to produce ethanol. The incentives protect the farmers in general and particularly corn farmers who supply ethanol. Producers of ethanol are also supported through various tax breaks, soft loan guarantees. While consumers benefit from lower vehicle taxes when they use ethanol blends as fuel for their vehicles.

Detchon (2007) states that the American economy depends on transportation which depends almost entirely on oil. This dependence on oil has certain risks such as the need for military action to protect access to oil, a drain of resources from the economy in order to purchase oil and a negative impact on climate change. President George Bush (2006) articulated America's oil dependence and said, "Keeping America competitive requires affordable energy. And here we have a serious problem: America is addicted to oil, which is often imported from unstable parts of the world." Tom Lasorda (2006) proposes a solution by stating that "Biofuels represent a huge opportunity to reduce fuel consumption and our dependence on foreign oil." Bill Ford (2006) agrees and says that "If we want a game changer and a game changer in very short term and in big numbers, then ethanol is a very good play for this country."

Ethanol from corn has the potential to reduce American dependency on oil (Balat, 2008). The use of corn as a raw material for ethanol production in other parts of the world including Malawi is controversial because corn is a staple food (Heisey and Smale, 1995). Ethanol production from corn does not therefore represent a pathway for ethanol production. However the use of aggressive legislation and tax incentives to encourage ethanol production and use echoes Brazil and could be a pathway to increase both production and use of ethanol.

2.14.3 Pathways for increasing ethanol production in China and India

According to Balat (2008), China accounts for about 9% of global bioethanol production, 80% of which is grain-based—mainly derived from corn, cassava and rice. Dufey (2006) says, India on the other hand accounts for 4% of global bioethanol production made from sugarcane only. Balat (2008) says bioethanol is by far the most widely used biofuel for transportation globally and sixty percent (60%) is from sugarcane while the remaining forty percent (40%) is from other crops. China is numbered among those countries successfully using agriculture wastes to produce ethanol (Khan *et al.*, 2012).

Ethanol in India is produced by fermentation of molasses which is a by-product of sugar manufacture. Sugar cane is grown exclusively by small holder farmers in India (Chipukunya and Kacelenga, 2011). India also has the distinction of being the largest sugar consumer in the world and this causes tension with the ethanol industry (Gonsalves, 2006).

The pathways suggested by Shinoj et al. (2011) for increasing the production of ethanol in India include the following:

a) **Increasing sugarcane production**

The required increase in ethanol production for the twenty percent (20%) blending target is estimated at three times that of the 2010 production levels. The yields of sugar cane per hectare must be significantly enhanced. It is acknowledged that ILUC issues could arise as some food crop land could switch to become fuel (energy) crop land. In the long term this may not be sustainable.

b) **Importing ethanol**

Importation of ethanol to meet the shortfall is another possibility for closing the gap between the rising demand of ethanol and the local supply. Policy as it stands does not allow the importation of ethanol. According to Shinoj et al. (2011, p.3), the cost of importation is prohibitive.

c) **Technology development**

Current methods of ethanol production need efficiency improvements. Biotechnology research to increase sugar cane yields per hectare and to increase the sugar content in sugar cane is a long term solution. Ethanol extraction techniques from molasses also require improvement in order to raise the yields of ethanol from molasses.

d) **Complimentary feed stocks**

Studies by Rao and Bantilan(2007) and Reddy et al., (2005) quoted by Shinoj et al. (2011) indicate that sweet sorghum can be used as an alternative or complimentary feed stock to sugar cane. Sweet sorghum like sugarcane has varieties with different juice to ethanol yields. Woods (2000) found that sweet sorghum (Keller) yields 561 litres of ethanol per hectare compared to sugarcane which yields 936 litres of ethanol per hectare. Sweet sorghum is complimentary to sugarcane as it is harvested in sugarcane off season (Woods, 2000). Other feed stocks such as bagasse, crop residues etc. commonly called second and third generation biofuels could also provide a long term solution (Raju *et al*., 2009).

2.14. 4 EU directive on increasing production of ethanol

Biofuels in the EU are used to fight climate change and achieve a twenty percent (20%) reduction of greenhouse gases (GHGs) emissions. It is estimated that transport fossil fuels are responsible for twenty percent (20%) of the GHGs in the EU and the major substitute for fossils is biofuels (European Parliament Council, 2009). According to the Directive 2009/28/EC, biofuels and bioliquids used mostly in transport must reduce greenhouse gases (GHG) by thirty five percent (35%). The targeted reduction of GHG emissions is fifty percent (50%) by the year 2017. This is part of the energy and climate change legislation in the EU (article 17). Biofuel and bioliquid sources are specified as those whose raw materials do not come from land with high biodiversity value or with high carbon stock (article 18). The EU biofuels strategy has three objectives as follows:

a) To promote biofuels in the EU and developing countries.

b) To prepare for the large scale use of biofuels.

c) To increase cooperation with developing countries in the sustainable production of biofuels. These objectives have spawned seven policy areas described in the next section (2.14.5).

2.14.5 Lessons from the EU strategy

a) The policy to stimulate sustainable biofuel production suggests that the market forces alone are not sufficient to achieve sustainable biofuel production. This agrees with Mitchell (2010), where he points out the need to actively support biofuel production on account of legacy opposition by the public and fossil suppliers. The research proposes to develop a framework to achieve sustainable biofuel production.

b) An awareness campaign of the advantages of biofuels must be embarked upon. The acceptance of the use of biofuels by the public is necessary. The link of biofuel use to climate change mitigation is to be highlighted to stimulate the demand for biofuels along with economic activity and job creation opportunities.

c) Policy guidelines are proposed to ensure the use of biofuels. Blending mandates are therefore consistent with this policy.

d) The EU policy is to promote feedstock production for biofuels. The push for second generation feedstock production implies a desire to exclude food crops from this initiative.
e) Biofuel standards are to be entrenched in the policy specifically to determine the acceptability of ethanol being imported into the EU. These standards are to test the production sustainability of imported ethanol.
f) The policy recognises the potential non-tariff barrier the standards may have for ethanol imported from third countries and offers aid specifically to support the development of sustainable biofuel production.
g) The development of second generation biofuels is to be vigorously pursued in the sustainability context of biofuel production.

The EU policy on biofuels hinges firmly on the sustainability of all biofuel related activities such as production, trade, and biofuel feedstock production.

2.14.6 Analysis

The genesis of the Brazil ethanol production strategy is connected to the sugar industry. This link has made sugarcane the feedstock of choice. According to Mitchell (2010), the production of ethanol in Brazil was to reduce dependence on fossil fuel and to reduce GHGs (harmful vehicle emissions). Barber *et.al.* (2008), says growing sugarcane is a pathway for the production of ethanol. According to Dunmore (2011), the growth of ethanol production in Brazil was seen as increasing the demand for land to grow more sugarcane for ethanol. This suggests that increasing the land under sugarcane was a pathway for increasing sugarcane ethanol. Goes *et.al.* (2011), shows that the increase of land area under sugar has grown by much less compared to the sugarcane yields over the same period (1940 to 2010). While the thrust of his analysis was to refute claims that natural forests were being displaced by sugarcane, he also showed that producing high yielding sugarcane was a pathway for increasing ethanol production. Xavier (2007), indicates that there are over five hundred (500) commercial sugarcane varieties in Brazil.

According to Balat (2008), corn is the main ethanol production feedstock in the United States of America. As in the Brazilian case the ethanol program in America is built around one feedstock corn. Strong government intervention through legislation in America has been a driver for the growth of ethanol production and use. The production of ethanol in the USA is for energy security and climate change (GHG reduction) management. The USA and Brazil are the leaders in ethanol production and use (Almeida, 2007). Voegele (2014), says the two nations account for seventy five percent (75%) of global ethanol production. However the use of corn as feedstock for ethanol production does not constitute a pathway for increasing ethanol production because corn is a food crop. Heisey and Smale (1995), confirm the primacy of corn as food especially in Malawi.

O"kray and Wu (2010), say China has been producing grain-based ethanol for decades mainly derived from corn, cassava and rice. The reason given for the slow growth of ethanol production in the past is the tension caused by using food crops to produce ethanol. As already mentioned corn in Malawi is a staple and cassava and rice are also food crops. The ethanol production feedstock used in China in the past does not qualify as a pathway for ethanol production for Malawi. According to Khan *et.al*. (2012), China is successfully using agriculture wastes to produce ethanol. This presents a possible pathway for increasing ethanol production. However it has been noted by Chevron (2012) that this feedstock represents second generation biofuels. According to Spencer (2011), China has developed two second generation ethanol plants.

The Indian scenario presents some pathways for increasing ethanol production. Sugarcane is the exclusive ethanol production feedstock in India (Gonsalves, 2006). There is however a difference with Brazil in that India does not allow the use of sugar to produce ethanol. According to Shinoj *et.al*. (2011), molasses a byproduct (or waste) at the end of the sugar production process is used as feed stock for ethanol production. As mentioned before increasing sugarcane hectares and hence molasses volumes represents a pathway for increasing ethanol production. The analysis by Shinoj et.al. (2011) of the Indian National Policy on Biofuels released in 2009, suggests some pathways for ethanol production, such as improved ethanol extraction methods from molasses, increasing sugarcane yields per hectare as well as increasing sugarcane juice yields. These suggestions resonate with the Malawi situation given that molasses is the only ethanol production feedstock in use. Woods (2000), suggests the use of sweet sorghum as a compliment to sugarcane as a way of increasing ethanol production without entering the food for fuel debate. According to Raju *et.al*. (2009) wood residues can be ethanol production feedstock. This would be second generation ethanol production which is not yet commercially available in Malawi and in many other countries (Spencer, 2011).

The analysis indicates pathways for increasing ethanol production. The reason given is so that the countries mentioned will reduce their dependence on oil (or fossil fuel), which is an energy security concern and manage climate change. The research question arising in respect of the first reason (fossil dependence reduction) for increasing ethanol production is posed as follows while climate change issues are discussed separately:

What should be done to make ethanol more significant in the Malawi liquid fuels portfolio? (Chapter 1, section 1.10)**.**

The influence of Government policies are reviewed in the light of this question on their effect or effectiveness on increasing biofuel production in the selected countries..

2.15 Government Policies to Incentivise Bioethanol Production

Literature reviewed on the production of ethanol (bioethanol) revealed that government policies that offered incentives for ethanol production helped increase the volume produced. The following presents the various instruments employed by the selected countries to incentivize ethanol production.

2.15.1 Brazil strategy for incentivising ethanol production

The Government of Brazil strategically supported sugar production for bioethanol by putting in place policies to incentivise bioethanol production (Er, 2011). The following are the specific policies and incentives that the Government of Brazil put in place as shortlisted by Mitchell (2010):

Government put in place incentives to encourage ethanol production. Over the long term, fuel companies should experience the benefits of using the ethanol blend and thus government intervention would give way to the market forces. For example, ethanol is now being used as a raw material to produce high-octane fuel ether additives like ETBE (ethyl tetra butyl ether), replacing the poisonous MTBE (methyl tetra butyl ether). Xavier (2007, p.5) lists the PROALCOOL program incentives in the following box :

PROALCOOL First Incentives

- Guaranteed alcohol price lower than gasoline price
- Guaranteed remuneration to the producer
- Loans for alcohol producers to increase their capacity
- Tax reduction for alcohol cars
- Mandatory alcohol selling in gas stations
- Maintenance of strategic alcohol stocks

A brief background of the incentives now follows.

a. According to Mitchell (2010), the price of ethanol at the filling station pump was set by the Brazilian government at sixty five percent (65%) of the price of petrol (gasoline). This was an incentive for motorists to use ethanol instead of petrol and as already noted by Xavier (2007) the measure was successful. However the strategy had difficulties in the years 1985 to 1988 when the oil prices fell sharply. When petroleum prices recovered, car manufacturers introduced flex-fuel vehicles powered by any mixture of petrol and bioethanol, thus providing the driver with a fuel choice which is cheaper or easily available. The range of fuel choices offered to motorists is from one hundred percent (100%) bioethanol, petrol blended with twenty to twenty five percent (20-25%) bioethanol or fossil fuels (petrol). In an environment of higher oil prices, the demand for both bioethanol powered cars and flexi-fuel cars have escalated (Er, 2011).

b. The incentives sought to guarantee the profitability of the sugar industry after the sharp fall of sugar prices in 1974. Thus sugar was used to produce ethanol instead of being exported.

c. PROALCOOL was both an energy security program and an agricultural subsidy program. The aim was to increase the production of ethanol from sugarcane for use as a gasoline substitute, but also to maintain the profitability of the sugar industry. The program allowed the excess production to be converted into ethanol in special distilleries close to the sugar mill. The ethanol thus produced would be blended with gasoline in a proportion of up to twenty four percent (24%).

d. The government offered extremely attractive credit guarantees and low-interest loans for the construction of new refineries and for ethanol production capacity expansion of the old ones. Government intervention made it easier for investors to enter the ethanol production sector. This had the effect of increasing ethanol volumes.

e. Vehicle owners of ethanol driven cars or flexi-fuel vehicles (FFVs) had lower taxes while car manufacturers of ethanol driven vehicles (EDVs) and taxis also received substantial tax breaks. This incentive created a demand for FFVs which in turn increased the demand for ethanol and drove up ethanol production.

f. A law was passed mandating all fuel filling stations to sell one hundred percent ethanol fuel. The availability of ethanol at every filling station ensured that FFV owners and ethanol driven vehicle owners had equal access to fuel as the owners of conventional vehicles.

   As a result of the 1973 oil crisis engendered by the OPEC embargo, the government maintains strategic ethanol stock reserves in case of a fuel shortage.

g. An economic development strategy must include ethanol production feedstock. The availability of more feed-stocks means, the ethanol production costs will decrease and contribute to economic growth.

h. Cross pollination across ethanol producing countries enhances the benefits of improvements in the production and marketing of ethanol. The government encouraged the export of expertise in ethanol production and marketing although Xavier (2007) says the Brazilian model may not be fully replicated in other countries.

2.15.2 North American strategy for incentivizing ethanol.

Corn ethanol has been produced and used in America since the 1800s. As already noted Henry Ford’s early cars were designed to run on ethanol (Ethanolhistory.com (2010 - 2011). Hoekman (2008), says the U.S. has enacted regulations and set goals to encourage increased usage of biofuels especially corn derived ethanol. The reasons given are energy security, diversity and sustainability as well as greenhouse mitigation. The state of California is the leader in aggressively promoting biofuel use and has a goal of 20% increase of renewables of total road transport fuels by 2020 and by 30% by 2030.

The Energy Policy Act (2005) has many provisions including energy efficiency and conservation, modernization of energy infrastructure and promotion of both traditional and renewable alternatives. Koplow (2007) quoted by Tiffany (2009) lists a number of tax incentives emanating from EPA (2005) which targeted corn ethanol production as well as ethanol use such as volumetric excise tax credits, market price support, reductions in state motor fuel taxes, federal grants, demonstration projects, research and development grants, accelerated depreciation on assets and federal small producer tax credit among others. The U.S. Congress passed the Energy Independence and Security Act (EISA) of 2007 (Hoekman, 2009). This act specifically incentivises biofuels from cellulosic material, that is second generation biofuels. Ethanol producers who use cellulosic raw materials get higher tax breaks compared to those still using corn. The aim is to secure food supplies and feedstock for animals. The incentives protect the farmers in general and particularly corn farmers who supply ethanol production plants. Ethanol producers are also incentivized through various tax breaks, soft loan guarantees. While consumers benefit from lower vehicle taxes if they use ethanol blends.

In summary the EPA (2005) was passed to protect corn farmers, corn ethanol producers and ethanol blend consumers. The next piece of legislation the EISA (2007) was passed to move the ethanol industry from corn towards cellulose to protect the corn feedstock industry. California and other states adopted goals more aggressive than the federal government to prioritise climate change issues in pursuing the use of ethanol.

2.15.3 China strategy for incentivising ethanol production

For over two decades China has been producing ethanol but issues concerning the use of food crops for ethanol have interfered with attempts to increase ethanol production (O’Kray and Wu, 2010). The ethanol production journey for

China is chronicled by O’Kray and Wu (2010) in the following. Ethanol development in China was done in three subsequent phases:

1. Demonstration phase: 1986 to 2001.
2. Legislative infrastructure, including financial incentives: 2001 to 2004
3. Expansion of successful pilot programs: 2004 onwards.

The Chinese central government selected Henan Province for the demonstration of ethanol production. The choice of Henan was based on the large wheat surplus harvests which were the feedstock for the initial four ethanol production plants. Government subsidised these grain ethanol production plants. Ethanol blending with petrol was piloted in three cities and was supervised by state agencies, the central planning commission and the China Petrochemical Corporation.

Four more ethanol production plants were set up. Regulations and enforcement of the E10 blend were set in motion. Ethanol production units using non-grain feedstock were actively encouraged by government and no new grain based ethanol production plants were allowed. Feedstocks allowed included sorghum, cassava and sweet potatoes. Government incentives for non- grain feedstock production plants were given. This practice ensured that ethanol production would not be stymied by market vagaries. A summary of the Chinese policies and incentives are as follows:

a) Government price regulation prevented competition with petrol from stifling the development of ethanol production and use in the transport sector.
b) Biofuel policy was embedded in the national five year development plans.
c) Permissible feedstocks specified initially were wheat. However as the pilot program took root grain feedstocks were forbidden. Non-grain feedstocks were specified such as sweet potatoes and cassava.
d) Government incentives for non- grain feedstock production plants were given. This practice ensured that ethanol production would not be stymied by market vagaries.

2.15.4 Indian biofuels strategy for incentivising ethanol production

India is the fourth largest ethanol producer after Brazil, the United States and China (Gonsalves, 2006). The government of India mandated the blending of 5% (five percent) ethanol in petrol in 2003 in the nine sugar producing States and Union Territories 1. Andhra Pradesh 1. Damman and Diu 2. Goa 2. Dadra and Nagar Haveli 3. Gujrat 3. Chandigarh 4. Haryana 4. Pondicherry 5. Karnataka 6. Maharashtra 7. Punjab 8. Tamilnadu 9. Uttar Pradesh (Government of India, 2002). A phased expansion of the ethanol blend to the rest of the country is planned. Cane and sugar prices in India are government controlled (Chipukunya and Kacelenga, 2011). Gonsalves (2006, p.5) believes that policies such as this one, which he labels "protectionist", are stifling domestic growth of both sugar and ethanol production. This view is contradicted by the Indian National Policy on Biofuels released in 2009 (Shinoj *et al*., 2011). The policy envisages enhancement of rural development thus generating employment opportunities. As a consequence of the use of biofuels on a large scale, environmental and economic benefits would be reaped. Gonsalves (2006) view is of the classical free market where prices find their own level. The Indian National Policy on biofuels deliberately sets out to empower rural populations as a development strategy by controlling prices.

Another aspect entrenched in the policy is that food related feedstocks would not be permitted, in order to avoid a conflict between food security and energy security. Notably ethanol from sugar cane molasses is included as coming from a non-food feedstock. Infrastructure such as irrigation canals, roads, water and power are provided free to sugar cane farmers by government. In addition no taxes are levied on sugar cane proceeds (Chipukunya and Kacelenga, 2011).

The blending of biofuels to twenty percent (20%) for both petrol and diesel is targeted to be achieved by 2017 (GoI, 2009). There are a number of challenges, the principal being, the cyclic nature of sugar production causing molasses shortages (Shinoj *et al.*, 2011). The result is that the five percent (5%) blending target for 2010 has not been met. An Increase in the price of ethanol is expected to help in reaching the targeted five percent (5%) blend by encouraging ethanol production. According to Shinoj et al. (2011, p.2) "Demand for petrol in India is galloping" due to rapid urbanisation, increasing incomes resulting in high vehicular density. Achieving the twenty percent (20%) blend by 2017 therefore requires measures to be put in place to anticipate the increased demand.

The Indian National Policy on biofuels as it stands does not allow the importation of ethanol. This means that ethanol demand in India must be met from local production and could be a pathway for increasing ethanol production. According to Shinoj et al. (2011, p.3), the cost of importation is prohibitive anyway.

2.15.5 EU Biofuels Strategy for incentivising ethanol production

According to Palacio (2000) almost eighty percent (80%) of the energy used in the EU is from fossils, where forty one percent (41%) is oil, with coal accounting for sixteen percent (16%) and natural gas at twenty two percent (22%). The strengthening of the renewable energy sector is intended to reduce the dependence on fossils by the EU. The Directive 2009/28/EC identifies the renewable energy sources as wind power, solar power (thermal and photovoltaic), hydro-electric power, tidal power, geothermal energy and biomass as having the potential " of reducing dependence on imported fossil fuels" (article 8). Demirbas (2006, p.955) concurs that “biomass has the potential to provide a cost-effective and sustainable supply of energy, while at the same time aiding countries in meeting their greenhouse gas reduction targets”.

The EU energy policy is wide ranging and has the aim of ensuring that the energy consumed in the EU is secure, competitive and sustainable (European Parliament, Council, 2009). According to Swinbank (2009), the EU’s environmental sustainability criterion could be challenged in the World Trade Organisation as it may be construed as a trade barrier. Swinbank (2009) quoted by Mitchell (2010) says the defence of the EU environmental sustainability criterion can be successfully made if it can be shown that it is nondiscriminatory and scientifically based and that it has been imposed only after meaningful negotiations with the EU’s main suppliers to develop international standards.

The supply problem of oil in the transport sector is seen as the most acute and impinging on energy security (article 2). Renewables and particularly biofuels are seen as the solution in reducing this fossil oil dependence hence enhancing energy security (Gonsalves, 2006, p.13).

Biofuels in the EU are used to fight climate change and achieve a twenty percent (20%) reduction of greenhouse gases (GHGs) emissions. It is estimated that transport fossil fuels are responsible for twenty percent (20%) of the GHGs in the EU and the major substitute for fossils is biofuels (European Parliament Council, 2009).

According to the Directive 2009/28/EC, biofuels and bioliquids used mostly in transport must reduce greenhouse gases (GHG) by thirty five percent (35%). The targeted reduction of GHG emissions is fifty percent (50%) by the year 2017. This is part of the energy and climate change legislation in the EU (article 17). Biofuel and bioliquid sources are specified as those whose raw materials do not come from land with high biodiversity value or with high carbon stock (article 18). As mentioned before (2.8.1) the EU biofuels strategy has three objectives as follows:

a) To promote biofuels in the EU and developing countries.
b) To prepare for the large scale use of biofuels.
c) To increase cooperation with developing countries in the sustainable production of biofuels. These objectives have spawned seven policy areas the policy areas targeting ethanol production are highlighted in the following:

Article 69 (European Parliament, Council, 2009) aims to stimulate the demand for biofuels by ensuring sustainable production of biofuels. To this end EU member states are to be encouraged to meet their individual biofuel consumption targets. Energy tax regimes are to be scrutinised to ensure that individual fuels are not damaging to the environment.

The policy articulated by Article (1, 74) (European Parliament, Council, 2009) deals with the development of the production and distribution of biofuels. Guidelines have been proposed to prevent practices that may prevent or discriminate against the introduction of biofuels by monitoring industries that use biofuels.

Article 12 of the policy specifies that animal by products and waste potential as feedstocks for biofuel production must be examined.

According to Article 29, 86 of the EU policy on biofuels (European Parliament, Council, 2009), the development of EU biofuel production and imported biofuels is to be enhanced via the trade opportunities of biofuels. Establishment of separate customs codes for biofuels is to be considered in this regard.

Another policy measure is the support of developing countries that have a biofuel potential especially those affected by the EU sugar reforms (article 74). This is to be done through aid programmes for biofuels and cooperation in the development of national biofuel policies and action plans.

Finally, research and innovation in improving production processes and lowering costs is to be supported (article 22). Full use of second generation biofuels and biomass is to be actively researched (article 66). The biofuels industry is to lead such efforts with a view to establishing a shared European vision and strategy for the production and use of biofuels. A summary of the EU policy on biofuel production follows:

a) The policy to stimulate sustainable biofuel production suggests that the market forces alone are not sufficient to achieve sustainable biofuel production. This agrees with Mitchell (2010), where he points out the need to actively support biofuel production on account of legacy opposition by the public and fossil suppliers. The research proposes to develop a framework to achieve sustainable biofuel production.

b) The EU policy is to promote feedstock production including animal products andwastes for biofuels. The push for second generation feedstock production implies a desire to exclude food crops from this initiative.

c) Biofuel standards are to be entrenched in the policy specifically to determine the acceptability of ethanol being imported into the EU. These standards are to test the production sustainability of imported ethanol and must not discriminate.

d) The policy recognises the potential non-tariff barrier the standards may have for ethanol imported from third countries and offers aid specifically to support the development of sustainable biofuel production.

e) The development of second generation biofuels is to be vigorously pursued in the sustainability context of biofuel production.

The EU policy on biofuels hinges firmly on the sustainability of all biofuel related activities such as production, trade, and biofuel feedstock production.

2.15.6 Analysis

The cases of Brazil, America, China, India and the EU cited indicate a strong policy intervention by governments in the quest for increasing ethanol production. Various policies were introduced at crucial times to ensure the growth of ethanol production.

Brazil has the oldest ethanol production regime which after almost three decades has shed off the many policies, save the blend mandate which is at twenty four percent (24%), that guided ethanol production (Xavier, 2007). Malawi in contrast has had no policy (Jumbe et.al., 2007). The blend mandate (Extra Ordinary Gazette 31st December, 2010) in place may represent an attempt to skip the developmental stages Brazil went through. The twenty four percent (24%) blend mandate in Brazil is higher than the twenty percent (20%) in Malawi. The Brazil ethanol regime (ProAlcool) was in response to the 1973 OPEC oil embargo, a similarity shared by Malawi (Mitchell, 2010). According to Barber et. al., (2008) sugar production for fuel grew as a result of this policy intervention. Johnson and Silveira (2014), commented that climate change imperatives gave birth to the 1986 Brazilian National Motor Vehicles Emissions Control programme where ethanol was used to address pollution in Brazil. This policy demonstrates the active policy intervention by Brazil in keeping the growth of ethanol production on course. Malawi has no policy on emissions per se. Subsequent policy initiatives in Brazil in the form of tax incentives led to the development of ethanol driven vehicles and FFVs a feat yet to be emulated (Xavier, 2007). The American strategy continues to be one using legislation to chart the future of ethanol production and use by incentivizing more the preferred type of feedstock.

The birth and growth of Chinese biofuel programme has from inception been controlled by the central government (O'Kray and Wu, 2010). The ethanol production feedstock used at the beginning was wheat, a food crop. A contrast with Malawi where molasses is the feedstock. The aim of the China biofuel programme was to combat the negative effects of high global oil prices due to the depleting resource and environmental pollution (Shinoj et. al., 2011). The environmental pollution dimension was not a factor when the Malawi National Energy Policy (NEP) came into effect and only mentions ethanol as a cause of inefficiency in the liquid fuels supply (Department of Energy Affairs, 2003, p.28, p.30, p.73). All stages of the China ethanol programme were state controlled from 1986 to date (O'Kray and Wu, 2010). The biofuel policy is embedded in the five year national development plan and provides for fuel price controls and offers incentives for ethanol production plants using non-food feedstocks. The absence of a biofuel policy in Malawi, as noted before, makes it difficult for policy intervention in the development of ethanol production.

The Indian National Biofuels Policy mandates a five percent (5%) blend of ethanol with petrol in nine of the twenty nine territories (Government of India, 2009). The mandated blend level of twenty percent (20%) in Malawi is higher although in practice due to the shortage of molasses the actual level achieved could be ten percent (10%) (Chanje, 1999). The phased approach used in India could conceivably be used in Malawi by targeting high vehicular density areas.
Price controls are a feature of the Indian Biofuels Policy which resonates with the Malawi fuel price build up (MERA, 2011). The price controls are a development strategy designed to empower the rural sugarcane farmers. The levies in the Malawi price build up however have nothing to do with sugarcane but target other development and administrative areas such as rural electrification, energy regulation and roads among others.

Shinoj *et. al*., (2011) notes that the Indian Biofuels policy specifically excludes food crops from being used as ethanol production feedstock. Molasses, a byproduct of the sugar production process is named as being a non-food product and therefore permissible as feedstock for ethanol production. Malawi has no biofuel policy or strategy beyond the blending mandate and cannot fully prevent food crops from being used as ethanol fuel production feedstock.

The policy restricts sugarcane farming to smallholder farmers. A move considered by Gonsalves (2006) as protectionist and stifling the growth of both the sugarcane industry and ethanol production. Malawi on the other hand has two sugarcane estates owned by one company and only about ten percent (10%) smallholder sugarcane farms (CARD, 2012).

Biofuels in the EU are primarily aimed primarily at climate change issues, as opposed to the rising prices of oil or the depleting oil resource as was the case with Brazil and Malawi. The EU biofuels policy is most wide ranging as opposed to the other policies which deal with ethanol (bioethanol). According to the European Parliament, Council (2009), a number of policies address biofuel production as follows:

a) Biofuel production must be sustainable and member countries must meet their biofuels consumption targets.
b) The use of animal by products and waste as biofuel feedstock is encouraged.
c) Trade opportunities are to be used to increase biofuel production via increased demand for biofuels.
d) Ethanol production in countries affected by the EU sugar reforms qualifies those countries to receive aid to develop biofuel policies.
e) Research into second and third generation biofuels is specifically encouraged.

As noted before intentional biofuel policies have made Brazil a leader in ethanol production while in the cases of India and China the growth of ethanol production is deliberately managed to side step controversial issues such as food for fuel. The research question posed in section 2.13.1 may find partial answers in biofuel policy formulation.

In the preceding paragraphs the pathways for increasing ethanol production were reviewed. The review found that governments have used different pathways for increasing ethanol production and have gone to the extent of providing incentives. The research question seeking to find the relevant pathways for increasing ethanol production in Malawi is as follows:

What should be done to make ethanol more significant in the Malawi liquid fuels portfolio? (Chapter 1, section 1.10)**.**

In the next section, the literature review focuses on pathways for increasing the use of ethanol.

2.16 Objective c). Find pathways for increasing use of ethanol

In the previous section literature pertaining to pathways for increasing ethanol production and the various government incentives for achieving this was reviewed. This section looks at literature pertaining to pathways for increasing the use of ethanol. The analysis at the end of this section will point out possible ways to increase the use of ethanol in Malawi and navigate the policy and strategy gaps that exist (Section 2.7).

2.16.1 Brazils pathways for increasing use of ethanol

Brazil has been using ethanol as a fuel since 1925 (Almeida, 2007). Today Brazil is a global leader in the use of bioethanol as a fuel source (Er, 2011). Following the oil embargo by the Oil Producing and Exporting Countries (OPEC) in the 1970s the Brazilian President Ernesto Geisel launched the National Alcohol Program (ProAlcool) in 1975. The aim of ProAlcool was to reduce the dependence of Brazil on imported fossil fuels by using more ethanol in vehicles. ProAlcool was also a response to the impact fossil oil prices had on Brazil's balance of payments (Mitchell, 2010). According to Barber *et.al.* (2008), sugar production for fuel also increased as a result.

First, the car industry was encouraged to market vehicles that ran on bioethanol rather than petrol through tax initiatives such as lowering the registration tax for ethanol vehicles. Manufacturers capitalised on this by retrofitting old vehicles so that they could run on ethanol as well as petrol. By 2003 manufacturers had developed the flexi-vehicle that runs on either ethanol or petrol or any combination of the two as more tax breaks related to biofuels use were enacted by Government (Johnson and Silveira, 2014).

Secondly, the price of bioethanol was capped at 65% the price of petrol. The result was that more people bought ethanol driven vehicles and demand for ethanol increased.. Further, the ethanol industry focused on the domestic market thereby limiting the price risk, given that the fossil fuel prices are controlled by government and the industry is able to respond to market signals by switching between sugar and ethanol production (Mitchell, 2010). A third initiative was mandatory blending of petrol with bioethanol and requiring that all fuel filing stations have pumps for one hundred percent (100%) bioethanol, the blended petrol and fossil fuel.

According to Mitchell (2010), a stimulus package for the development of cars using hydrous ethanol was another incentive offered by government to spur the use of ethanol. Hydrous ethanol contains more water than the anhydrous ethanol with a purity of ninety six point five percent (96.5%) and is cheaper to produce. In the previous section 2.8.2 policies and incentives for increased ethanol production have been presented. Some policies impacted both the production and use of ethanol. A selection from the shortlist by Xavier (2007), of the incentives granted by the Brazilian government aimed at specifically increasing ethanol use is presented:

a) Government guaranteed that the ethanol price would be lower than the petrol price through price controls. This had the effect of increasing demand for ethanol hence ethanol use.
b) Remuneration to the sugar producer was guaranteed by government. The sugar industry and ethanol industry in Brazil are linked. When the export price of sugar falls as happened in 1974, sugar is used to produce ethanol for domestic use. The sugar producer is thus protected from the vagaries of the sugar market while ensuring the availability of ethanol for the motoring public.
c) The tax reduction incentive for ethanol driven vehicles and FFVs had the effect of increasing the demand for such vehicles and thus the use of ethanol.
d) Mandatory ethanol selling of ethanol at fuel filling stations made it easier for the public to own EDVs and FFVs and thus increased the use of ethanol.

It is noted that ethanol is most widely used for transportation globally and sixty percent (60%) of it is from sugarcane while the remaining forty percent (40%) is from other crops (Balat, 2008).

2.16.2 The American biofuels strategy

According to Tiffany (2009), U.S. policy initiatives and incentives have for many years favoured the production of ethanol from corn. The goals have been to increase corn prices and farmer income, enhance rural employment through encouragement of value-added businesses, increase energy security, and produce additives and/or fuels capable of reducing tailpipe pollutants and greenhouse gases. Ethanol produced from corn was heavily supported during the OPEC oil embargo of the 1970s. The American hostage situation in Iran during that period spurred the search for alternative fuel as crude oil prices became untenable. Three laws were passed in America to promote biofuel use (Tiffany, 2009).

2.16.3 The Chinese strategy for increasing use of ethanol

In 2001 an ethanol standard was established and regulations promulgated for production, distribution and sales. E10 blending was legislated for use in automobiles and rolled out into strategic areas of China. The Bioethanol Utilization Plan was included in the 10th Five-Year Program (2001-2005), where the use of biofuels and the type of raw materials were stipulated. The blended petrol (gasohol) price was strictly regulated and parity with petrol maintained.

The path for the development of biofuels specifically ethanol use in China has some notable lessons regarding government intervention for ethanol use as follows:

a) Government price regulation prevented competition with petrol from stifling the development of ethanol production and use in the transport sector.
b) Biofuel policy was embedded in the national five year development plans.

2.16.4 The Indian Biofuels Strategy

The Indian Biofuels policy focuses on the enhancement of rural development thus generating employment opportunities. The large scale use of biofuels would then benefit the environment and economy (Shinoj et.al., 2011). The free market view by Gonsalves (2006) is where prices find their own level. In contrast the Indian National Policy deliberately sets out to empower rural populations as a development strategy by controlling prices. In addition no taxes are levied on sugar cane proceeds (Chipukunya and Kacelenga, 2011). Price controls and tax initiatives by government serve to increase the use of ethanol.

According to Shinoj et al. (2011, p.2) rapid urbanization and rising incomes are resulting in more vehicles on the road thus fueling the "Demand for petrol in

India". This in turn increases the use of ethanol. The policy has a goal of achieving twenty percent (20%) blend by 2017; therefore measures must be put in place to anticipate the increased demand. The pathways suggested by Shinoj et al. (2011) for increasing ethanol use include importing ethanol.

Importation of ethanol to meet the shortfall is a possibility for closing the gap between the rising demand of ethanol and the local supply in India. However the policy as it stands does not allow the importation of ethanol. According to Shinoj et al. (2011, p.3), the cost of importation is prohibitive anyway.

There are important lessons that the researcher learned from India including the following:

a) The price controls in the policy mean that free market forces cannot influence sugarcane farming for fuel.
b) The phased expansion strategy of ethanol blend in fuel is recommended as a start up measure. For example the policy allowed for blending to commence initially in nine (9) states out of the twenty nine (29).
c) Another recommendation is that the growth of ethanol demand must be anticipated in the policy. The phased introduction of ethanol blending, for example, embedded in the policy means the demand for ethanol can be monitored and managed as it grows.

2.16.5 EU Biofuels Strategy for increasing use of ethanol

As explained in section 2.8.2 the EU strategy is to use biofuels to reduce fossil fuel dependence in the transport sector (Palacio, 2000). The strengthening of the renewable energy sector is intended to achieve this. According to the Directive 2009/28/EC, renewable energy sources as wind power, solar power (thermal and photovoltaic), hydro-electric power, tidal power, geothermal energy and biomass have the potential of weaning the transport sector from relying on imported fossil fuels (article 8). The use of biomass to produce biofuels is recognized as a cost-effective sustainable source of energy (Demirbas, 2006). The role of biofuels in GHG mitigation is a major reason for their use (European Parliament, Council, 2009).

Article 17 of the Directive 2009/28/EC urges the use of biofuels in the context of climate change and sets targets for GHG reduction. The EU biofuels directive has policy areas aimed at increasing the use of biofuels including ethanol.

Article 69 of the directive, encourages EU member states to use biofuels and meet their consumption targets. This it is postulated would increase the demand for biofuels and increase the use of biofuels. Guidelines have been proposed to monitor industries that use biofuels and ensure that there is no bias against some biofuels or their origins. The use of biofuels is to be encouraged by highlighting economic activity and job creation opportunities (article 1, 86).

Expanding feedstock supplies is another initiative for promoting the use of biofuels in the EU (article 89). Article 74 of the directive focuses on countries affected by the EU sugar reforms and Malawi is one of them. Aid programmes are proposed to help in the drafting of national biofuel policies to increase the use of biofuels among other things. Further according to article 66 of the directive, the full use of second generation biofuels and biomass is to be researched by the biofuels industry.

The following are important lessons from the EU:

a) Policy guidelines are proposed to ensure the use of biofuels. Blending mandates are therefore consistent with this policy.
b) The development of second generation biofuels is to be vigorously pursued in the sustainability context of biofuel production.

2.16.6 Analysis

Ethanol use in Brazil was increased through a combination of strategic legislation and incentives. ProAlcool was aimed at reducing vehicular emissions and this led to incentives directed at car manufacturers thus producing EDVs and FFVs (Johnson and Silveira, 2014). No other ethanol programme has matched this feat. A series of price controls aimed at increasing ethanol use and production were enacted as described in section 2.8.2. The notable one is where the ethanol price is capped at sixty five percent (65%) of the petrol price (Xavier, 2007). In Malawi MERA (2011) publishes maximum fuel pump prices every time the world oil prices move. This as noted before does not target increasing ethanol use in Malawi (section 2.8.2).

In China, price regulation in the biofuel policy is vigorous and is aimed at keeping the price of petrol higher than ethanol for the growth of ethanol use and production. The Indian price control regime on the other hand is not for the growth of ethanol use but for benefiting the sugarcane farmers.

The sugarcane industry in Brazil is protected by government interventions when the sugar prices are unfavourable (Xavier, 2007). The sugar industry and ethanol industry in Brazil are linked. In the case of Malawi there are no government interventions to protect the sugar industry. The ethanol industry's connection with sugar is via the sale of molasses to the ethanol companies by the sugar company. The sugar prices in India are regulated for the benefit of the small holder farmer and do not target incentivizing ethanol use.

The blending mandate in Brazil stipulates that all fuel filling stations must supply ethanol as a standalone fuel (100% ethanol), blended petrol with ethanol (up to 24% ethanol) and fossil fuel. This increases ethanol use since FFV owners will gravitate towards ethanol due to the lower price of ethanol and availability. As noted before the biofuels policy containing the ethanol price controls in China is embedded in the national development plan. The effect is that the growth of ethanol use in China is guaranteed. In the Indian biofuels policy ethanol blending with petrol is mandated for certain areas only. Ethanol use increases as the number of areas mandated increases. Theoretically all petrol sold in Malawi is blended with ethanol according to the mandate in the Gazette of 31 December 2010. However as noted earlier there is a shortage of molasses and therefore not enough ethanol to blend all the petrol (Chapter 1, section 1.5.1). Further Malawi still does recognize ethanol as a standalone fuel and there is no requirement for ethanol dispensing pumps at filling stations. As Chinamulungu (2016), observes the stalling of initiatives such as the EDV in Malawi leaving the standalone fuel issue unresolved regress rather than increase ethanol use. Ethanol use increases only as the volume of molasses and petrol increases. The question then arises as to how ethanol use can be increased in Malawi. The research question is appropriately framed as follows:

How can the use of ethanol be increased? (Chapter 1, section 1.10)**.**

In this section, the researcher reviewed literature pertaining to increased use of ethanol. He established that there are many ways of increasing the use of ethanol. In the next section the researcher investigated sustainability criteria for the production and use of ethanol.

2.17. Objective d): Investigate sustainability criteria for production and use

The question of the sustainability of the production and use for ethanol are receiving more and more attention. The fourth objective, therefore, discusses the sustainability criteria for ethanol production and use.

2.17.1 Ethanol sustainability

According to Trines et al., (2006) cited by Fumo (2009), assessing sustainability involves identifying environmental, economic and distributional or social criteria. Lisa Jackson the EPA (Environmental Protection Agency) administrator in 2009, quoted by Hecht (2011), says “biofuels sustainability research will provide better information to decision makers on the tradeoffs and opportunities of increased biofuel production”. There is recognition that sustainability research may inform criteria selection. Fiksel et al., (2012, p.6), states that *“many sustainability frameworks have been proposed and used by different organizations around the world. ………. The choice of an appropriate conceptual framework and corresponding indicators is heavily dependent upon an individual’s purpose, worldview, and system of values”.*

The large number of sustainability frameworks with caveats dependent on individual purposes, world views and values make it difficult to apply in a given situation. It follows that there will be a large number of definitions and criteria of sustainability. The following is a synopsis of a few sustainability definitions and criteria.

Purchas and Hutchinson (2008, p.5) in their report on biofuel sustainability defined it as "the ability to produce biofuels to contribute to today’s fuel needs without compromising the ability of productive land to meet current and future food and fuel needs". Issues considered under the sustainability banner include environmental (land use change, fertilizer use, biodiversity, energy intensity), social (labour conditions, land ownership) and economic (net benefit).

According to Barber et al. (2008, p.6) "sustainability criteria are generally poorly defined". Broad sustainability criteria by Barber et al., (2008) embrace the following:

a) Greenhouse gas (GHG) emissions and energy balance
b) Sugarcane production (land use (LUC or ILUC), fertilizer, water use, agrichemicals, mechanisation)
c) Flora and fauna protection (biodiversity, forests)
d) Ecological impacts (GHGs emissions = air pollution, water pollution, soil erosion)
e) Economic impacts (food versus fuel and land prices, costs)

European Parliament, Council (2009) Directive 2009/28/EC specifies criteria similar to those noted by Barber (2008). The directive seeks to encompass imported biofuels as well. According to Mitchell (2010, p.110), "Ethanol produced from sugarcane or molasses directly benefits from duty-free access and should meet the EU's default minimum criterion for reducing GHGs". Brieskorn (2011) summarises the major biofuels concerns in the EU as follows:

a) Competition with food (price spikes 2007/2008)
b) Land use change (direct and indirect)
c) Loss of biodiversity
d) Loss of GHG sinks
e) Other sustainability effects: Locally (soil, water, air) and Social (poverty, land rights)

Safeguarding biodiversity is another of the criteria mentioned and Groom et al. (2008) mention in very broad terms that land under biofuel crops must be minimised. The Table 2.12.1(a) developed by Batidzirai (2007) demonstrates that land used for agricultural is a small fraction of the land available. In the case of the SADC region which includes Malawi, Mozambique, Zimbabwe, Congo DR, South Africa, Zambia and Tanzania only five and a half percent (5.5%) of the available land is actually cultivated. None of the countries or regions shown cultivate close to one hundred percent (100%) of the available land. India has the highest at fifty seven percent (57%). The implication is that the debate on land for food going for fuel needs to be balanced with such data.

Table 2.17.1 (a) Land use summary

Land Use Summary for SADC and other selected countries/regions

Country/Region	Total Land Area	Forest Area		Agricultural Areas		Cultivated Area	
UNITS:	Million ha	Million ha	share of total land area	Million ha	share of total land area	Million ha	share of total land area
Total SADC	**964**	**368**	**38%**	**433**	**45%**	**53**	**5,5%**
Brazil	846	544	64%	264	31%	67	7,9%
China	933	163	18%	555	59%	155	16,6%
India	297	64	22%	181	61%	170	57,1%
United States	916	226	25%	409	45%	176	19,2%
EU-15	313	116	37%	140	45%	85	27,0%

Source: Batidzirai (2007)

The assertion by Spencer (2011) that “The world produces enough food to feed everyone” on the basis that world agriculture produces seventeen percent (17%) more calories per person today than it did thirty (30) years ago despite a seventy percent (70%) population increase, serves to widen the debate around food and biofuels. In quoting the Executive Director of the UN World Food Programme, Spencer (2011) places food shortages at the door of fossil fuel prices rather than biofuels taking up land for food.

According to Shinoj et al., (2011), the Indian National Biofuels Policy avoids the food versus fuel debate by excluding food related feedstocks. This way a conflict between food security and energy security is neutralised. Notably ethanol from sugar cane molasses is included as coming from a non-food feedstock.

To sum it up, Barber et al., (2008) add that it is possible to set various sustainability criteria but “to collect sufficient information” or data is difficult.

Jumbe et al., (2007) confirms that environmental and economic dimensions of biofuels have received wide attention in biofuel policies and assessments. Continuing debates over for example the effect of biofuels on food prices (fuel versus food) and over large versus small-scale biofuel production demonstrate the non-universality of the sustainability criteria. Butler (2014) cites the case of sugar growers and villagers in Dwangwa in Malawi, tussling over land. This is about small landowners who grow food crops such as maize and sugarcane being pressured into joining sugarcane grower schemes. According to Butler (2014), “The problem is that the economics of sugar production with its demand for irrigation and other inputs, only lends itself to larger plots”. This conflict is not about land for food going for fuel but is rather smallholder sugarcane farming being taken over by estates. Illovo the only sugar cane estate owners in Malawi deny that they are a party in this conflict.

Table 2.17.1 (b) Sustainability Criteria by Fumo

Ethanol production sustainablity criteria	Remarks	Code
Positive contribution to Malawi liquid fuel volume as an import substitute	Malawi imports all of its liquid petroleum (fossil) fuels (DEPARTMENT OF ENERGY AFFAIRS, 2003; NSO, 2011). The main reason is that no oil deposit has been verified yet. Biofuels would reduce the imported volume either through the mandated blending route or as stand-alone fuels. Ethanol is the only mandated biofuel for blending.	C1
Improves air quality (pollution) through emissions reduction	As cited by a number of authors (Ahmad *et al.*, 2013; Buis, 2011; Low and Isserman, 2009; Balat, 2008; Saka et.al., 2005) ethanol blended fuels burn cleaner and produce lower emissions and hence less air pollution.	C2
Land use: Competes with food crops	The concept of land use change (LUC) or indirect land use change (ILUC) alleges that agricultural land is being used for energy crops due to the drive to increase biofuel production (Dunmore, 2011; Barber et.al., 2008).	C3
Protects water quality (pollution)	It is known that fossil fuel emissions have an adverse effect on ground water (Mitchell, 2010). The use of ethanol blended fuels reduces emissions significantly and therefore water pollution (Demirbas and Demirbas, 2010).	C4
Affects soil erosion	The LUC or ILUC concept postulates that woodland is being cleared rapidly to make way for energy crops thus increasing the rate of soil erosion (McGrath, 2013; Lendle and Schaus, 2010).	C5
Affects price	Land prices are postulated as rising due to the demand for energy crops (Taheripour, 2012).	

of land	This suggests that increased ethanol production would have an upward push on land prices (Lendle and Schaus, 2010; Barber et al., 2008), .	C6
Affects biodiversity (forests)	Rapid development of energy crops to meet biofuel demand may damage biodiversity (Groom, 2008; Barber et al., 2008; European Parliament Council, 2009; Brieskorn, 2011).	C7
Affects forex availability as an import substitution	Ethanol used as a blend with petrol or as a standalone fuel reduces the amount of foreign exchange spent on fuel imports (NSO, 2011). This is a positive impact on the economy. “Price fluctuations result in a flow of foreign exchange resources to oil producers, which would otherwise be used to stimulate the economy” (Nkomo, p20, 2009). Positive forex effect (Van Zyl, 2007; Brieskorn, 2011; Kambatata, 2012; Sundu, 2012)	C8
Affects food prices	Increased ethanol production is seen as having an adverse impact on food crop land prices. As energy crops take up more land, food prices rise (Taheripour, 2012).	C9
Contributes to job creation	Rising demand for ethanol will mean more feedstock production and therefore more people to work the land (Mitchell, 2010).	C10
Reduces use of charcoal	It is thought that increased ethanol production will lead to reduced charcoal use as the rural population switches from wood to ethanol. Literature demonstrates a mixed reality (Crooks, 2009).	C11
Improves energy security	Ethanol acts as a hedge in case petroleum supplies are interrupted and therefore improves energy security (Nkomo, 2009).	C12
Increases water usage	Ethanol production uses a lot of water in the production process, through irrigation. However most of the water is reclaimable.	C13
Affects national import costs	Ethanol use positively impacts import costs since more ethanol means less petroleum imported, given that petroleum fuel has the highest import bill (NSO, 2011).	C14
Reduces dependence on imported oil	Increased ethanol production reduces the volume of imported petroleum fuel and consequently dependence on imported oil (Nkomo, 2010).	C15
Positive impact on economy	If ethanol use actually lowers the import bill via reduced fuel imports or freight and storage costs, then the economy benefits (Nkomo, 2009).	C16
Impacts on local culture - social welfare	Crop rotation of traditional food crops with energy crops means more small farmers will work for money as opposed to just subsistence food farming.	C17

Source: Fumo (2009)

The literature shows that certain criteria are more frequently referred to than others indicating that an attempt at consensus in the ordering of sustainability criteria is emerging but not finalised. Generally GHGs (or climate change issues), ILUC and economic benefit are at the top of many lists. Table 2.17.1 (b) is an adaptation for Malawi of criteria developed by Fumo (2009). Economic benefit or contribution was at the top of the list by Fumo (2009). The remarks are a summary of the literature reviewed. The codes shown under the code column are to facilitate analysis of data generated during this research.

2.17.2 Analysis

More attention is being paid to issues of sustainability for ethanol production and use. Broad areas to be considered in assessing sustainability are environmental, economic and distributional or social criteria (Fumo, 2009). Literature shows that there is tension between increasing ethanol production and sustainability (Hecht, 2011). The resolution of this apparent tension lies in agreeing uniform sustainability criteria. This position does not appear within reach because according to Fiksel et.al. (2012) there are many sustainability frameworks whose application depends on individual world views, value systems and purpose. For this reason there is a large number of definitions of sustainability.

Purchas and Hutchinson (2008) consider the environmental sustainability criteria as including land use change (LUC), fertilizer use, biodiversity and energy intensity. LUC brings in the notion that ethanol production is taking up land for food. Batidzirai (2007) shows that for the SADC region land under sugarcane is quite small and cannot be the cause of high food prices. On the other hand Spencer (2011) argues that the world produces enough food for everyone on the basis of calories required per person and that the cause of high food prices is high fossil fuel prices. As Barber et. al. (2008) notes it is difficult to reach a consensus on criteria for sustainability. This is partly due to the complex task of information gathering using non-uniform methods. However the areas frequently featured on most sustainability criteria lists are GHG mitigation, LUC (or ILUC) and economic benefit.

This review is the point of departure into the investigation of what sustainability criteria should be considered for Malawi biofuels production and use. The following research question was therefore considered :

What criteria should be considered in determining biofuel sustainability?
(Chapter 1, section 1.10)

2.18 The Frameworks

The outcome of this research is a Strategic Framework for Malawi for increasing the production and use of ethanol. The researcher, therefore, reviewed literature pertaining to frameworks in order to learn from other countries how they had formulated their frameworks. The frameworks were compared and contrasted and the relevant pillars noted for inclusion in the Malawi Strategic Framework. In addition, other pillars were identified which were included in the framework. Loppacher and Kerr (2005), Demibras and Balat (2006) and Biofuelindonesia (2007) confirm that liquid fossil fuels have been shown to be historically linked to biofuels. Balat (2008) asserted that bioethanol is by far the most widely used biofuel for transport energy globally.

The following sections (2.18.1 to 2.18.5) are devoted to exploring how biofuels have been instrumental in bridging the energy gap between demand and supply in various countries and regions. The milestones will inform the research in the development of an appropriate framework for ethanol production and use.

2.18.1 The Brazilian Biofuels Framework

Brazil has been using ethanol as a fuel since 1925 (Almeida, 2007). The front runner status of Brazil in ethanol production and use is rivaled only by the USA. According to Voegele (2014), the two nations account for over seventy five percent (75%) of global ethanol production.

Following the oil embargo by the Oil Producing and Exporting Countries (OPEC) in the 1970s the Brazilian President Ernesto Geisel launched the National Alcohol Program (ProAlcool) in 1975. The aim of ProAlcool was to reduce the dependence of Brazil on imported fossil fuels by using more ethanol in vehicles. ProAlcool was also a response to the impact fossil oil prices had on Brazil's balance of payments (Mitchell, 2010). This response had the effect of increasing sugar production for fuel (Barber *et al*., 2008). The ProAlcool program had some fundamental policy instruments to make consistent policies regarding the use and production of ethanol. Mitchell (2010, p.189) lists the policy instruments as follows:

a) A mandate for blending anhydrous ethanol (99.5% v/v) in all gasoline (petrol) distributed in the country at the maximum level admissible by the existing practice which was initially at twelve (12) percent by volume and was subsequently raised to eighteen (18) percent and then to the current (2010) blend of 20–25 percent.

b) Stimulus package for the development of cars using hydrous ethanol. Hydrous ethanol contains more water than the anhydrous ethanol with a purity of ninety six point five percent (96.5%).

c) Credit facilities at favorable interest rates for investment in ethanol distilleries.

In 1986, another program was set in motion in Brazil to address air pollution. Vehicle exhaust emissions were targeted especially in the urban areas. The program was called the National Motor Vehicle Emissions Control. According to Johnson and Silveira (2014), the objectives of the program were manifold including the following:

a) To reduce pollution by cutting emissions from motor vehicles.
b) To promote technological development in automotive engineering, testing, and measuring of pollutants.
c) Create programs of inspection and maintenance for vehicles in use.
d) Sensitise the population regarding air pollution issues particularly motor vehicle emissions.
e) Determine methods to evaluate program results.
f) Encourage research into improvements of liquid fuels in order to reduce polluting emissions.

The program is credited with significant pollution reductions from vehicles for the period prior to 1980 when petrol did not have a prescribed ethanol blend ratio. According to Mitchell (2010), a ninety six percent (96%) reduction of carbon monoxide, hydrocarbons, nitrogen oxide (NOx), and total aldehydes had been achieved by 2008.

The Government of Brazil strategically supported sugar production for bioethanol by putting in place policies to incentivise bioethanol production (Er, 2011). First, the car industry was encouraged to market vehicles that ran on bioethanol rather than petrol through tax initiatives such as lowering the registration tax for ethanol vehicles. Manufacturers capitalised on this by retrofitting old vehicles so that they could run on ethanol as well as petrol. By 2003 manufacturers had developed the flexi-vehicle that runs on either bioethanol or petrol or any combination of the two as more tax breaks related to biofuels use were enacted by Government (Johnson and Silveira, 2014).

Secondly, the price of bioethanol was capped at 65% the price of petrol. The effect was that public support for the ethanol driven vehicles increased and grew the market for such vehicles. Further, the ethanol industry focused on the domestic market thereby limiting the price risk, given that the fossil fuel prices are controlled by government and the industry is able to respond to market signals by switching between sugar and ethanol production (Mitchell, 2010). A third initiative was mandatory blending of petrol with bioethanol and requiring that all fuel filing stations have pumps for bioethanol and the blended petrol.

The Brazilian bioethanol programme is the largest and most successful in the world but there were drawbacks along the way such as concerns that the demand for sugar for bioethanol production was taking up land for food. The controversy centers on indirect land use change (ILUC), a relatively new concept that the rapid expansion of biofuel production in recent years is driving up the overall demand for agricultural land (Dunmore, 2011). According to Barber et al., (2008, p.6) there is little information available in the area of ILUC and "what has been published is conflicting and based on limited data and a large number of assumptions". McGrath (2013) agrees and points out that current research has not found any clear bias towards biofuel crops in the context of land acquisitions labeled 'land grabs'. According to Gnansounou and Dauriat (2011), "land-use change is included with details in only a few studies". Lendle and Schaus (2010, p.8) commenting on the Brazilian Cerrado (a highly biodiverse area) state that "it is believed that sugar cane expansion puts relatively low pressure on protected areas because it mainly takes place on former pasture land, but the impact on indirect land-use change is not yet fully understood". A study on feasibility of biofuels by Takavarasha et.al, (2005) commissioned by SADC reported that biofuels will not displace land and agricultural resources for food security, but will stimulate investment in agriculture by opening new markets for farmers who produce the feedstocks for biofuels and ensure access to food and better living conditions. The study further reported that biofuels will contribute positively to food security. In the Malawi context, Nalivata and Mapemba (p.43, 2012), describe the "Impact of Biofuels on Food Crops and Livestock Production in

Malawi" and say "Experience from the time these farmers were allowed to grow burley tobacco in addition to the dark-fired and sun-dried tobacco types, no significant food insecurity was reported in the country. Even presently, with subsidized fertilizer program that was once extended to fertilizer used in the production of burley tobacco and the good tobacco prices that once were prevalent at the tobacco Auction Floors, these did not make the farmers to be irrational and stop growing food crops in search of good money". It is observed that small holder farmers in Malawi do not swap land meant for food for cash crops. CARD (p.15, 2012), says, "The country [Malawi] should take advantage of what it knows: bioethanol is a tried and true option that can be expanded".

According to Goes et al., (2011), area under sugarcane has grown by 35% from 1940 to 2010 while sugarcane yields per hectare have grown by 43% from 40 tons per hectare (TCH) to 79TCH in the same period. Landell et al., (2010) quoted by Goes et al., (2011, p.3) claim that yields of 150TCH are achievable. The global average TCH is quoted at 70.2 by Pham (2014). This suggests that land requirements for sugarcane cultivation can be greatly reduced via the use of new high yielding sugarcane varieties. Another concern was the increased mechanisation of sugarcane harvesting leading to job losses.

There are some lessons that the researcher learned from Brazil. The lessons are documented in the paragraphs that follow. Brazil's global stature from ethanol continues to grow attended by reduced deforestation and economic growth. These assertions are not universally accepted as shown by the divisions on biofuel benefits in the EU (Bourguignon, 2015). However, Brazil is a global reference point for a successful ethanol program (Almeida, 2007; Mitchell, 2010). According to Xavier (2007), the Brazilian national alcohol program, PROALCOOL was both an energy security program and an agricultural price support program.

A brief synopsis of some lessons from the Brazilian experience is given by Mitchell (2010) as follows:

a) Government policies on biofuels such as ethanol need to be consistent over time. The reasons include fostering private sector confidence and reducing investor uncertainty. Building strong public commitment to biofuels is necessary to overcome resistance and opposition from existing fuel suppliers. Consumers support must be secured to achieve a successful biofuels regime.

b) A blending mandate for anhydrous ethanol and petrol at a minimum of ten percent (10%) initially is recommended in order to contain blending costs and achieve meaningful emission reductions while allowing growth and improvements in relevant technology. If volumes of ethanol are insufficient for country wide coverage, a phased approach is a reasonable way to proceed.

c) Vinasse is effluent from the processing of ethanol and should have strict disposal standards in the environmental regulations in order to protect ground water. The regulation should encourage the use of water conservation or reclamation technologies.

Discharges into the air and the use of octane enhancers such as tetra ethyl lead (TEL)must have stringent standards which will encourage and support the use of renewable fuels such ethanol. By 1921, it was known that ethanol was an effective antiknock agent, but TEL was introduced instead mainly for commercial reasons by the oil companies (Kitman, 2000). Ethanol blend into petrol ups the octane rating (Ahmad *et al.,* 2013). "Ethanol has a higher octane number (108), broader flammability limits, higher flame speeds, and higher heats of vaporization than gasoline. These properties allow for a higher compression ratio, shorter burn time, and leaner burn engine, which lead to theoretical efficiency advantages over gasoline in an ICE" (internal combustion engine) (Demirbas, 2008, p.1479)

d) Fuel ethanol must have a standard specification that ethanol producers and fuel distributors should follow to guarantee consistent quality supply to the consumer.

e) Incentives to encourage ethanol production must be provided initially by the government. Over the long term, fuel companies should experience the benefits of using the ethanol blend and thus government intervention would give way to the market forces. For example, ethanol is now being used as a raw material to produce high-octane fuel ether additives like ETBE (ethyl tetra butyl ether), replacing the poisonous MTBE (methyl tetra butyl ether). Xavier (2007, p.5) lists the PROALCOOL program incentives in the following :

PROALCOOL First Incentives

- Guaranteed alcohol price lower than gasoline price
- Guaranteed remuneration to the producer
- Loans for alcohol producers to increase their capacity
- Tax reduction for alcohol cars
- Mandatory alcohol selling in gas stations
- Maintenance of strategic alcohol stocks

f) An economic development strategy must include ethanol production feedstock. The availability of more feedstocks means, the ethanol production costs will decrease and contribute to economic growth.

g) Cross pollination across ethanol producing countries enhances the benefits of improvements in the production and marketing of ethanol.

The preceding section shows that for Brazil to successfully produce and use ethanol, it had to: enact legislation, come up with government supported incentives, introduce PROALCOOL, credit facilities, stimulus package and a mandate for blending. All these were investigated in order to see their suitability for inclusion into the Malawi Strategic Framework. The results of the research are in Chapter 4.

2.18.2 North American Framework

The United States biofuels program is ranked highly (Demirbas and Balat, 2006). As noted already ethanol in the USA has been used as fuel since the 1800s and especially during World War I. According to Curtis (2010), the Office of Energy Efficiency and Renewable Energy's (EERE) Biomass Program in the U.S. Department of Energy (DOE) is set up to help transform "renewable and abundant biomass resources into cost competitive high performance biofuels, bioproducts and biopower". The Biomass Program supports the EERE's four key priority areas as follows:

a) Dramatically reduce dependence on foreign oil

b) Promote the use of diverse, domestic and sustainable energy resources
c) Reduce carbon emissions from energy production and consumption
d) Establish a domestic bioindustry.

DOE (2014) says the United States energy endeavours will be mainly aimed at securing access to oil and reducing demand for energy while developing other sources. Other western nations will have a similar energy agenda given the security instability around oil producer nations (Pippard, 2010). Hoekman (2008), says the U.S. has enacted regulations and set goals to encourage increased usage of biofuels especially corn derived ethanol. The reasons given are energy security, diversity and sustainability as well as greenhouse mitigation. As Tiffany (2009, p.44) puts it “the primary goal of using this fuel is the reduction of emissions that contribute to ozone formation; an additional goal is the reduction of toxic emissions such as benzene”. The state of California is the leader in aggressively promoting biofuel use and has a goal of 20% increase of renewables of total road transport fuels by 2020 and by 30% by 2030.

On the national level the Energy Policy Act (2005) has many provisions including energy efficiency and conservation, modernization of energy infrastructure and promotion of both traditional and renewable alternatives. Koplow (2007) quoted by Tiffany (2009) lists a number of tax incentives emanating from EPA (2005) which targeted corn ethanol production as well as ethanol use such as volumetric excise tax credits, market price support, reductions in state motor fuel taxes, federal grants, demonstration projects, research and development grants, accelerated depreciation on assets and federal small producer tax credit among others. The U.S. Congress passed the Energy Independence and Security Act of 2007 (Hoekman, 2009). This act specifically incentivises biofuels from cellulosic material, that is second generation biofuels and raises the renewable fuel standard (RFS). Ethanol producers who use cellulosic raw materials get higher tax breaks compared to those still using corn. The aim is to use lass corn for fuel since corn is in the food chain via livestock feed. The incentives protect the farmers in general and particularly corn farmers who supply ethanol production plants. Ethanol producers are also incentivized through various tax breaks, soft loan guarantees. While consumers benefit from lower vehicle taxes if they use ethanol blends. The Farm Bill of 2008 has among its provisions direct payments to corn producers, sets prices for corn for four years to 2012, sets loan rates for corn for marketing assistance, definition of advanced biofuels and stipulates the payment quantums to cellulosic fuel ethanol producers among others (Food Conservation and Energy Act, 2008). This bill among other things targets moving ethanol production away from corn feedstock to cellulose.

According to Detchon (2007), the American economy depends on transportation and transportation depends almost entirely on oil. This dependence has certain risks such as the need for military action to protect access to oil, a drain of resources from the economy in order to purchase oil and increased global warming. President George Bush (2006) articulated America's dependence on oil and said, "Keeping America competitive requires affordable energy. And here we have a serious problem: America is addicted to oil, which is often imported from unstable parts of the world." (Hoekman, 2009).

Tom Lasorda (Chrysler Group President and CEO press release, 2006) proposed a solution by stating that "Biofuels represent a huge opportunity to reduce fuel consumption and our dependence on foreign oil." Bill Ford (Chairman of Ford, 2006) agrees and says that "If we want a game changer and a game changer in very short term and in big numbers, then ethanol is a very good play for this country." Ethanol is seen as having the potential to reduce America's oil dependence. Ethanol in America is mainly produced from corn (Balat, 2008). Bill Ford's (Chairman of Ford, 2006) comment suggests that the potential weaning of America from the exclusive use of fossil oil as a transport energy source by ethanol ought to be pursued to its logical conclusion. This research is about making ethanol a significant fuel in Malawi in order to reduce fossil oil dependency. The use of corn as a raw material for ethanol production in other parts of the world including Malawi is controversial because corn is a staple food (Heisey and Smale, 1995).

Corn ethanol production and use in the USA has been supported by government at federal and state level through legislation using various subsidies and grants and tax incentives to corn farmers, ethanol producers and ethanol blend users. Strong intervention by government is also noted as the USA moves from first generation ethanol production to second generation (cellulosic) ethanol production. The Farm Bill 2014 repeals most of the support corn ethanol that was available through Farm Bill 2008 (Agricultural Act, 2014).

Lessons

The following is a summary of the literature review on American corn ethanol:

a) The biofuels program is aimed at reducing oil dependence. American transport depends almost entirely on oil and as observed by President George Bush events elsewhere threaten the security of oil supply.
b) Mitigation of harmful emissions (GHG). The laws enacted such as the EPA 2005 and the Farm Bill 2008 specifically target GHGs and offer incentives for lowering such emissions.
c) The Federal government enacts laws to protect corn farmers from market vagaries. Corn farmers get grants and payments to guarantee their incomes. Part of the rationale is that corn is livestock feedstock and therefore in the human food chain.
d) Individual states also have laws to encourage ethanol production. Notably California has ambitious targets to reduce vehicle emissions by promoting ethanol production and use.
e) These laws also fix the market price of many agricultural commodities among them corn. Corn prices are fixed by law so that farmers continue producing corn.
f) Ethanol producers have grants and tax credits to encourage production. Up to 2008 corn ethanol plants were eligible for a number of incentives.
g) Blend mandates are still less than 10% due to cutting back of corn as a feedstock for ethanol and the still growing cellulose ethanol production apart from the large American vehicle fleet most of which does not run on ethanol.
h) The Agriculture Act 2014 repeals most of the grants, payments and tax credits for corn ethanol in the Farm Bill 2008 in favour of ethanol produced from cellulose (second generation ethanol). An example of strong government control of biofuel policy and strategy.

The following Section 2.18.3 looks at the Asian scenario and has more insights on the food versus fuel debate.

2.18.3 The Chinese Biofuels Framework

According to O'Kray and Wu (2010), China is the second largest energy consumer in the world after the United States of America. The energy sources are dominated by coal and oil, which are heavy pollutants and non-renewable. The rapid economic development of China and India is putting enormous pressure on the price of oil due to the demand (Jumbe *et.al*, 2007). The oil demand in China is largely for transportation fuels (O'Kray and Wu, 2010). The negative consequences of fossil oil dependence, such as environmental pollution, rising oil prices, depleting oil reserves and other problems are bringing to the fore the search for renewable energy alternatives to oil.

Biofuels in China present a unique opportunity to solve the energy dilemma (O'Kray and Wu, 2010). This imperative has made China one of the largest bioethanol and sugar producers and consumer coming behind only Brazil and the United States of America (Gonsalves, 2006). According to Balat (2008), China accounts for about 9% of global bioethanol production, 80% of which is grain-based—mainly derived from corn, cassava and rice. India on the other hand accounts for 4% of global bioethanol production made from sugarcane only (Dufey, 2006). Balat (2008) says bioethanol is by far the most widely used biofuel for transportation globally and sixty percent (60%) is from sugarcane while the remaining forty percent (40%) is from other crops. China is numbered among those countries successfully using agriculture wastes to produce ethanol (Khan *et al.*, 2012).

China has been producing ethanol for over two decades and has had difficulties rapidly increasing production due to food security concerns (O'Kray and Wu, 2010). The ethanol production journey for China is chronicled by O'Kray and Wu (2010) in the following. Ethanol development in China was done in three subsequent phases: demonstration phase: 1986 to 2001, legislative infrastructure, including financial incentives: 2001 to 2004, expansion of successful pilot programs: 2004 onwards. The phases are explained fully in the paragraphs that follow.

a. Demonstration phase

The Chinese central government selected Henan Province for the demonstration of ethanol production. The choice of Henan was based on the large wheat surplus harvests which were the feedstock for the initial four ethanol production plants. Government subsidised these grain ethanol production plants. Ethanol blending with petrol was piloted in three cities and was supervised by state agencies, the central planning commission and the China Petrochemical Corporation.

b. Legislative phase

In 2001 an ethanol standard was established and regulations promulgated for production, distribution and sales. E10 blending was legislated for use in automobiles and rolled out into strategic areas of China. The Bioethanol Utilization Plan was included in the 10th Five-Year Program (2001-2005), where the use of biofuels and the type of raw materials were stipulated. The blend (gasohol) price was strictly regulated and parity with petrol maintained.

c. Expansion of pilot program

In the third phase five more provinces were allowed to roll out the use of the E10 blend. Four more ethanol production plants were set up. Regulations and enforcement of the E10 blend were set in motion. Ethanol production units using non-grain feedstock were actively encouraged by government and no new grain based ethanol production plants were allowed. Feedstocks allowed included sorghum, cassava and sweet potatoes.

The path for the development of ethanol production and use in China has some notable lessons as follows:

a) Complete government involvement in the initial phase. The first four production plants were Government controlled.

b) Phased introduction of ethanol blended fuel. This approach ensured the success of the pilot plants allowing for gradual growth of ethanol production capacity.

c) Government price regulation prevented competition with petrol from stifling the development of ethanol production and use in the transport sector.

d) Biofuel policy was embedded in the national five year development plans.

e) Permissible feedstocks specified initially were wheat. However as the pilot program took root grain feedstocks were forbidden. Non-grain feedstocks were specified such as sweet potatoes and cassava.

f) Government incentives for non- grain feedstock production plants were given. This practice ensured that ethanol production would not be stymied by market vagaries.

The experience of China presents a different framework for promoting the development of ethanol as a biofuel. First, Government is at the center of the whole exercise. Government controlled the initial production of ethanol specified the permissible feedstocks, set ethanol and petrol prices and ensured that the biofuel policy was part of the national development plan.

2.18.4 The Indian Biofuels Framework

India is the fourth largest ethanol producer after Brazil, the United States and China (Gonsalves, 2006). Ethanol in India is produced by fermentation of molasses which is a by-product of sugar manufacture. Sugar cane is grown exclusively by small holder farmers in India (Chipukunya and Kacelenga, 2011). India also has the distinction of being the largest sugar consumer in the world and this causes tension with the ethanol industry (Gonsalves, 2006).

The government of India mandated the blending of 5% (five percent) ethanol in petrol in 2003 in the nine sugar producing States and Union Territories 1. Andhra Pradesh 1. Damman and Diu 2. Goa 2. Dadra and Nagar Haveli 3. Gujrat 3. Chandigarh 4. Haryana 4. Pondicherry 5. Karnataka 6. Maharashtra 7. Punjab 8. Tamilnadu 9. Uttar Pradesh (Government of India, 2002). A phased expansion of the ethanol blend to the rest of the country is planned. Cane and sugar prices in India are government controlled (Chipukunya and Kacelenga, 2011). Gonsalves (2006, p.5) believes that policies such as this one, which he labels “protectionist”, are stifling domestic growth of both sugar and ethanol production. This view is contradicted by the Indian National Policy on Biofuels released in 2009 (Shinoj *et al*., 2011). The policy envisages enhancement of rural development thus generating employment opportunities. As a consequence of the use of biofuels on a large scale, environmental and economic benefits would be reaped. Gonsalves (2006) view is of the classical free market where prices find their own level. Whereas the Indian National Policy deliberately sets out to empower rural populations as a development strategy by controlling prices.

Another aspect entrenched in the policy is that food related feedstocks would not be permitted, in order to avoid a conflict between food security and energy security. Notably ethanol from sugar cane molasses is included as coming from a non-food feedstock. Infrastructure such as irrigation canals, roads, water and power are provided free to sugar cane farmers by government. In addition no taxes are levied on sugar cane proceeds (Chipukunya and Kacelenga, 2011).

The blending of biofuels to twenty percent (20%) for both petrol and diesel is targeted to be achieved by 2017 (GoI, 2009). There are a number of challenges, the principal being, the cyclic nature of sugar production causing molasses shortages (Shinoj *et al.*, 2011). The result is that the five percent (5%) blending target for 2010 has not been met. An Increase in the price of ethanol is expected to help in reaching the targeted five percent (5%) blend by encouraging ethanol production. According to Shinoj et al. (2011, p.2) "Demand for petrol in India is galloping" due to rapid urbanisation, increasing incomes resulting in high vehicular density. Achieving the twenty percent (20%) blend by 2017 therefore requires measures to be put in place to anticipate the increased demand. The pathways suggested by Shinoj et al. (2011) include the following:

a) Increasing ethanol production

The required increase in ethanol production for the twenty percent (20%) blending target is estimated at three times that of the 2010 production levels. The yields of sugar cane per hectare must be significantly enhanced. It is acknowledged that ILUC issues could arise as some food crop land could switch to become fuel (energy) crop land. In the long term this may not be sustainable.

b) Importing ethanol

Importation of ethanol to meet the shortfall is another possibility for closing the gap between the rising demand of ethanol and the local supply. Policy as it stands does not allow the importation of ethanol. According to Shinoj et al. (2011, p.3), the cost of importation is prohibitive.

c) Technology development

Current methods of ethanol production need efficiency improvements. Biotechnology research to increase sugar cane yields per hectare and to increase the sugar content in sugar cane is a long term solution. Ethanol extraction techniques from molasses also require improvement in order to raise the yields of ethanol from molasses.

d) Complimentary feed stocks

Studies by Rao and Bantilan, 2007 and Reddy *et al*., 2005 quoted by Shinoj et al. (2011) indicate that sweet sorghum can be used as an alternative or complimentary feed stock to sugar cane. Sweet sorghum like sugarcane has varieties with different juice to ethanol yields. Woods (2000) found that sweet sorghum (Keller) yields 561 litres of ethanol per hectare compared to sugarcane which yields 936 litres of ethanol per hectare. Sweet sorghum is complimentary to sugarcane as it is harvested in sugarcane off season (Woods, 2000). Other feed stocks such as bagasse, crop residues etc. commonly called second and third generation biofuels could also provide a long term solution (Raju *et al*., 2009).

Lessons

a) A robust government biofuels policy is necessary to forestall arguments about indirect land use change (ILUC) and fuel versus food issues. Sugar is considered a food item in India consequently sugarcane cannot be grown for producing fuel ethanol. The price controls mean that free market forces cannot influence sugarcane farming for fuel.

b) Phase expansion of ethanol blend in fuel. As a start up measure the blending of ethanol with petrol should be done in bits. For example the policy allowed for blending to commence initially in nine (9) states out of the twenty nine (29).

c) No food related feedstock is allowed. The policy lists raw materials that maybe used in the production of ethanol. This ensures the exclusion of food crops that can be used to produce ethanol such as cassava.

d) Sugar cane molasses is non-food feedstock. The policy classifies molasses, a by-product of sugar production, as being a non-food item. This allows molasses to be used in the production of ethanol.

e) Anticipate growth of ethanol demand in the policy. The phased introduction of ethanol blending embedded in the policy means the demand for ethanol can be monitored and managed as it grows.

The notable feature of the Indian biofuel framework for promoting the development of ethanol is that it limits the growing of sugarcane to small holder farmers. Further the roll out of the blend mandate is phased.

2.18.5 EU Biofuels Framework

According to Palacio (2000) almost eighty percent (80%) of the energy used in the EU is from fossils, where forty one percent (41%) is oil, with coal accounting for sixteen percent (16%) and natural gas at twenty two percent (22%). The Directive 2009/28/EC identifies the renewable energy sources as wind power, solar power (thermal and photovoltaic), hydro-electric power, tidal power, geothermal energy and biomass as having the potential " of reducing dependence on imported fossil fuels" (article 8). Demirbas (2006, p.955) concurs that “biomass has the potential to provide a cost-effective and sustainable supply of energy, while at the same time aiding countries in meeting their greenhouse gas reduction targets”.

The EU energy policy is wide ranging and has the aim of ensuring that the energy consumed in the EU is secure, competitive and sustainable (European Parliament, Council, 2009). According to Swinbank (2009), the EU’s environmental sustainability criterion could be challenged in the World Trade Organisation as it may be construed as a trade barrier. Swinbank (2009) quoted by Mitchell (2010) says the defense of the EU environmental sustainability criterion can be successfully made if it can be shown that it is nondiscriminatory and scientifically based and that it has been imposed only after meaningful negotiations with the EU’s main suppliers to develop international standards.

The supply problem of oil in the transport sector is seen as the most acute and impinging on energy security (article 2). Renewables and particularly biofuels are seen as the solution in reducing this fossil oil dependence hence enhancing energy security (Gonsalves, 2006, p.13).

Biofuels in the EU are used to fight climate change and achieve a twenty percent (20%) reduction of greenhouse gases (GHGs) emissions. It is estimated that transport fossil fuels are responsible for twenty percent (20%) of the GHGs in the EU and the major substitute for fossils is biofuels (European Parliament Council, 2009).

According to the Directive 2009/28/EC, biofuels and bioliquids used mostly in transport must reduce greenhouse gases (GHG) by thirty five percent (35%). The targeted reduction of GHG emissions is fifty percent (50%) by the year 2017. This is part of the energy and climate change legislation in the EU (article 17). Biofuel and bioliquid sources are specified as those whose raw materials do not come from land with high biodiversity value or with high carbon stock (article 18).

The EU biofuels strategy has three objectives as follows:

a. To promote biofuels in the EU and developing countries.
b. To prepare for the large scale use of biofuels.
c. To increase cooperation with developing countries in the sustainable production of biofuels. These objectives have spawned seven policy areas described as follows.

The first measure envisaged is to stimulate the demand for biofuels by ensuring sustainable production of biofuels (article 69). Member states are to be encouraged to meet their individual biofuel consumption targets. Energy tax regimes are to be scrutinised to ensure they protect the environment by checking that individual fuel's performance is environmentally friendly.

The second measure is to ensure that biofuel advantages are highlighted and clearly linked to the reduction of GHGs (article 80). A guarantee that feed stock used for biofuel production is sustainable both in the EU and in third countries. The compatibility of technical and environmental regulations regarding blending ratios for petrol and diesel must be taken into consideration.

A third strategic measure is the development of the production and distribution of biofuels (article 1, 74). Guidelines have been proposed to prevent practices that may hinder the introduction of biofuels or discriminate against them by monitoring industries that use biofuels. Economic activity and job creation opportunities are to be highlighted to encourage biofuel consumption (article 1, 86).

Expanding feedstock supplies constitutes yet another measure in promoting the use of biofuels in the EU (article 89).

An awareness campaign on second generation biofuels sources such as cereals and forest residues to foresters and farmers is to be funded. Animal by products and waste are to be examined as possible feed stocks for biofuel production (article 12).

A fifth measure is the enhancement of the trade opportunities of biofuels (article 29, 86). Establishment of separate customs codes for biofuels is to be considered in this regard. The approach on trade with ethanol producing countries must ensure sustainable development of EU production and imported biofuels. A revision of biofuel standards is to be submitted.

The sixth measure is the support of developing countries that have a biofuel potential especially those affected by the EU sugar reforms (article 74). This is to be done through aid programmes for biofuels and cooperation in the development of national biofuel policies and action plans.

Finally, research and innovation in improving production processes and lowering costs is to be supported (article 22). Full use of second generation biofuels and biomass is to be actively researched (article 66). The biofuels industry is to lead such efforts with a view to establishing a shared European vision and strategy for the production and use of biofuels.
The following are the lessons from the EU:

a) The policy to stimulate sustainable biofuel production suggests that the market forces alone are not sufficient to achieve sustainable biofuel production. This agrees with Mitchell (2010), where he points out the need to actively support biofuel production on account of legacy opposition by the public and fossil suppliers. The research proposes to develop a framework to achieve sustainable biofuel production.

b) An awareness campaign of the advantages of biofuels must be embarked upon. The acceptance of the use of biofuels by the public is necessary. The link of biofuel use to climate change mitigation is to be highlighted to stimulate the demand for biofuels along with economic activity and job creation opportunities.

c) Policy guidelines are proposed to ensure the use of biofuels. Blending mandates are therefore consistent with this policy.

d) The EU policy is to promote feedstock production for biofuels. The push for second generation feedstock production implies a desire to exclude food crops from this initiative.

e) Biofuel standards are to be entrenched in the policy specifically to determine the acceptability of ethanol being imported into the EU. These standards are to test the production sustainability of imported ethanol.

f) The policy recognises the potential non-tariff barrier the standards may have for ethanol imported from third countries and offers aid specifically to support the development of sustainable biofuel production.

g) The development of second generation biofuels is to be vigorously pursued in the sustainability context of biofuel production.

The EU policy on biofuels hinges firmly on the sustainability of all biofuel related activities such as production, trade, and biofuel feedstock production.

The biofuel policies (or frameworks) for the selected countries and regions presented will be synthesized in order to develop a biofuel framework for Malawi, drawing on the lessons learned in the literature review. The literature review highlights the advantages of biofuels which are presented in the following sections.

2.19 Biofuel advantages

According to Barber et al. (2008), there are quite a few advantages to supplementing petroleum with biofuels such as sugarcane ethanol. Petroleum is more toxic, more dangerous to health and produces more life threatening pollutants than ethanol (Balat, 2011). Van Zyl (2007) cites the advantages of biofuels for African countries specifically as first a source of foreign exchange savings for oil-deprived countries. The second advantage is the boosting of local agriculture production, additional markets and revenue for farmers. Thirdly biofuels help to generate employment and local economic growth. Finally biofuels reduce GHG emissions and preserve the quality of the atmosphere.

The world price of fossil fuel is very high and continues to rise (Figure 2.10). In addition fossil fuel sources are depleting and are not renewable (Grubb, 2011). The virtues of biofuels as an alternative sustainable energy source are being extolled, but are apparently not being exploited enough (Buis, 2011). According to Low and Isserman (2009), ethanol is an alluring political solution for a range of problems from global warming to national energy security to local economic development.

Climate change is another driver for increased biofuels production because, according to Mitchell (2010), advanced biofuels can achieve a fifty percent (50%) reduction of GHGs. Examples of the advanced or second generation biofuels include cellulosic biofuels, biomass-based diesel, and ethanol from sugarcane (p.106). However according to Demirbas (2005a, p.328) “Conversion technologies for producing bioethanol from cellulosic biomass resources such as forest materials, agricultural residues and urban wastes are under development and have not yet been demonstrated commercially”. However Spencer (2011) lists Brazil, China, Thailand, and India as the developing countries that have already successfully developed a first-generation biofuel industry. These countries are also at various stages of research and development of second generation biofuels as follows:

a) A pilot plant has been set up in Brazil.

b) China has two pilot plants in operation.

c) In Thailand, research is currently underway in several universities.

Second-generation biofuels demand in the EU and the US will be the impetus for second generation biofuels growth in developing countries. Rastogi (2011) believes that by 2050, Africa could provide twenty five percent (25%) of the world's bio-energy by using second generation technologies.

Opinion on the advantages of biofuels is by no means monolithic. For example the response to the policy direction announced by the EC Director General for Energy on 17th October, 2012, aimed at driving the production and consumption of next generation biofuels in the EU clearly demonstrates the multiplicity of opinion (Cressy, 2012).

Biofuels in the EU generate a great deal of debate stemming from a desire to reduce transport fuel emissions, generally called the greenhouse gases (GHG). Biofuels are recognised as a pathway to combat climate change (Directive 2009/28/EC). There is a contention that casts some biofuels as bad because the feed stocks are food crops or because they use land that might be used for growing food - this is the land use change (LUC) or ILUC (indirect land use change) argument. Some biofuels, it is argued, increase rather than decrease GHGs (Brieskorn, 2011). According to Pandey et al. (p.30, 2011), “indirect land-use change (land-use changes due to displaced activities or biomass use) is more complex as the indirect conversion of land is a global and dynamic issue that is difficult to relate accurately to biofuels production, more research works are needed for improving the methodologies on this aspect”. The European Commission is proposing changes in current biofuels legislation through the directives on Renewable Energy 1 and the Fuel Quality 2. The following are the proposed changes:

a) To increase the minimum GHG saving threshold for new installations to sixty percent (60%) in order to improve biofuel production efficiencies while discouraging further investments in low GHG performance installations.

b) To include ILUC factors in the reporting by fuel suppliers of GHG savings on biofuels and bioliquids by EU member states.

c) To limit food crop based biofuels that can be counted towards the EU's ten percent (10%) target of renewable energy in the transport sector by 2020 to the current five percent (5%) up to 2020 while maintaining the reduction targets for renewable energy and carbon intensity.

d) To provide market incentives for biofuels with no or low GHG emissions, particularly second and third generation biofuels produced from feed stocks that do not require more land.

The proposals by the EU Energy Commissioner have implications for first generation biofuels and are being rebutted by ethanol producer associations, and the European Biodiesel Board among others (EBB, 2006). The basis for the rebuttal is as follows:

a) The LUC reporting in both directives is erroneously based on the International Food Policy Research Institute (IFPRI) report which is not peer reviewed. This, it is argued, will discourage investments in advanced biofuels (also known as second generation biofuels).

b) The five percent (5%) cap on biofuels disadvantages the member states that already have targets higher than the five percent (5%) and will cause an abrupt slowdown on biofuels production thus affecting jobs and industrial activity. These changes will negatively affect the sugar crushing industry.

c) Policy decision changes, just after two years of making them, destroys the existing companies who will be the platform for introducing advanced biofuels.

d) The linkage between biofuels and food security and food prices is faulty. It is argued that the reverse is true in that biofuels production stimulates the production of other products for the food and feed chain in the EU.

These persuasive arguments on either side of the debate demonstrate the difficulty of a one size fits all approach to biofuels production. The circumstances of EU member states are not uniform. Extrapolating this to the global scene makes it obvious that the differences are even wider and so a case by case approach is probably more workable.

Malawi has no biofuels policy (section 2.7). However the production and use of ethanol has been going on since 1982. This research aims to develop a strategic framework for sustainably promoting ethanol production to make ethanol a significant part of the liquid fuels portfolio and reduce fossil fuel dependence in Malawi. The evolution of biofuel frameworks or policies, from other countries or regions has been examined as a step in this direction.

2.19.1 The advantages of biofuels cited in the Malawi context

According to the National Statistics Office (NSO, 2014), the top four items making up the Malawi import bill in 2014 were petroleum products at three hundred and seventy nine (379) million United States Dollars representing 13.5% of total imports, machinery and equipment came second at 10% while medical supplies were third at 8.8%% followed by fertilisers at 7.5%.

Ethanol blending with petrol is a practice dating back to 1982 as explained before (Chapter 1, section 1). However the impact on the import bill and the other benefits accruing from this practice are not highlighted. The benefits include the following:

a) Foreign exchange saving.
All fuels in Malawi are imported (NSO, 2014) and the 20% blend ratio of ethanol to petrol represents a maximum of 20% saving of foreign exchange (forex) on petrol imports. Brieskorn (2011) shows forex saving as an advantage of ethanol use.

b) Land-lockedness and reduction of freight costs.
From Figure 11 it can be seen that Malawi is surrounded by Mozambique (south, east, west), Zambia to the west and Tanzania to the north and has no direct route to the sea. Consequently imports have to be freighted long distances inland (Chirwa, 2015). Ethanol blending saves part of this freight bill to the extent that a volume of petrol is blended.

c) Reduction of dependency on imported petrol
Since ethanol is locally produced, it increases energy independence and improves energy security (Nkomo, 2009). Ethanol is a strategic commodity in case access to the sea ports is cut out by civil unrest in neighbouring countries, as happened during the civil war in Mozambique

in the seventies (Robinson, 2009). Natural disasters such as floods can also cause disruption to fuel supplies (Jooste, 2010).

d) Renewable Energy

Ethanol is produced from biological renewable sources, in this case sugarcane molasses. This is unlike depending on fossil fuels that are depleting with time (Umbach, 2010). The use of renewable energy sources is being promoted globally. According to Garnier (2012), most renewable energy technologies are too expensive. Renewable energy technologies are therefore out of reach for most Malawians. Ethanol blending with petrol is a more viable option.

e) Ethanol as Octane Booster

Ethanol blend into petrol ups the octane rating (Ahmad *et al.,* 2013). Malawi has a choice of importing lower-octane rating petrol and then boost it up with ethanol blending. According to Gonsalves (2006, p.14), "the energy content of ethanol is only 26.9 MJ/kg compared to 44.0 MJ/kg for petrol. This would suggest that the fuel economy (km/litre) of a petrol-powered engine would be 38.9 per cent higher than that of an ethanol-powered engine. In actuality, this difference is 30 per cent since ethanol engines can run more efficiently (at a higher compression ratio) because of the higher octane rating. For a 10 per cent ethanol blend the fuel economy advantage of a petrol engine is only 3 per cent". This analysis shows that Malawi would save significant expense since lower-octane fuels cost less per barrel than the high-octane fuels.

f) Ethanol as an Oxygenate

Oxygenated fuels burn more cleanly and more efficiently (Ahmad *et al.,* 2013). Ethanol whose molecular formula is C_2H_5OH has oxygen and acts as an oxygenate in ethanol blended fuels. Ethanol is now being used as a raw material to produce high- octane fuel ether additives like ETBE (ethyl tetra butyl ether), replacing the poisonous MTBE (methyl tetra butyl ether).

g) Cleaner Environment

Environmentally, the use of ethanol blends reduces carbon dioxide by promoting more complete combustion (European Parliament Council, 2009; Ahmad *et al.,* 2013). There is a net reduction of carbon dioxide emissions into the atmosphere. Carbon dioxide is a normal product of burning fuels that contribute to global warming. Cane growing absorbs more carbon dioxide than is released by manufacturing and using ethanol (Herrera, 1997). Ethanol blended fuels reduce the net green house gases thereby protecting the ozone layer and decelerating the global warming. There is a major health benefit with cleaner air. This feeds into Government efforts to reduce the national budget for health (Nkomo, 2009). In some countries, users of environmentally sound technologies earn a grant from the Global Environmental Fund. This, apart from environmental protection, would also act as a forex source for Malawi.

h) Economic opportunities for Malawians

Ethanol production has opened up employment opportunities for Malawians. Ethanol Company (ETHCO) and PressCane Ltd are 92% and 100% respectively, Malawian owned local companies. Small holder sugarcane growers have a chance of expanding their production as ethanol production grows (Chipukunya and Kacelenga, 2011). Ethanol creates jobs in preparation of land, planting, maintenance, harvesting, transporting raw material and final product and processing (Fumo, 2009).

Other non-food agricultural-products such as wood, straw, biodegradable waste can be used as feed for ethanol plants (Sun and Cheng, 2005). This would increase agricultural activity in Malawi and positively impact on employment. Rural incomes would improve and jobs would be generated among many other benefits if ethanol use in Africa approached its potential (Rastogi, 2011).

As already mentioned opinion regarding the advantages of biofuels and ethanol in particular is not unified (section 2.19). In the following are some of the arguments against the production and use of ethanol.

2.19.2 The disadvantages of biofuels

Anh-Thu and West (2004) present disadvantages of ethanol use as follows:

a) Aldehydes are produced by the use of ethanol fuel in blends above 23% and is a threat to nose, eyes and throat and it is postulated that cancer can result. Catalytic converters are suggested as appropriate mitigation.

b) Ethanol blend pricing is not consumer friendly.

c) Energy value of ethanol fuel is lower than petrol. Consequently more ethanol than petrol is required for the same distance.

d) Ethanol absorbs water that could reduce its effectiveness as a fuel.

e) Ethanol is an effective solvent so when used as a fuel it could clean the system and deposit the dirt in the engine if fuel filtration is inadequate.

f) Ethanol is more explosive than petrol and therefore needs greater handling care.

The conclusions of Anh-Thu and West (2004) include a citation of the Brazilian experience as a model going forward and mentions all the advantages referred to in section 2.19.1.

The benefits of ethanol have real implications for Malawi, for example, sugar cane growing already has put a large number (5,400 permanent and 4,500 seasonal) of people to work (Illovo Sugar (Malawi) Limited, 2013). If more sugarcane were grown to increase the ethanol volume, even more people would find jobs.

The ethanol programmes of Brazil, India and other countries provide over whelming evidence that the advantages of ethanol outweigh the disadvantages (Directive 2009/28/EC). A brief synopsis of how the disadvantages have been mitigated follows.

a) The hypothetical health issues cited by Anh-Thu and West (2004) have largely been mitigated by the introduction of flexi vehicles in Brazil (Mitchell, 2010).

b) Ethanol pricing methods vary from country to country but there is consensus that ethanol has to be attractively priced relative to petrol (Xavier, 2007; Shinoj et al., 2011; Mitchell, 2010).

c) The energy value of ethanol is indeed lower that petrol, however the benefits accruing from the use of ethanol fuel compensate for this downside (2.12.2). Another compelling reason for the promotion of ethanol use is the fact that fossil deposits are dwindling and irreplaceable (Umbach, 2010; Crooks, 2013; Hubbert, 1956).

d) Ahmad et al. (2013) articulates the combustion advantages of the presence of water in ethanol. In consequence the objection no longer holds.

e) The introduction of the flexi vehicle has technologically dealt with the corrosive nature of ethanol in that components in vehicle fuel systems are no longer susceptible to attack by ethanol (Ahmad et al. ,2013).

f) The greater explosiveness of ethanol has been turned into an advantage in that lower octane fossil fuels, which are cheaper, have their ratings improved (2.12.2).

Literature confirms that the use of biofuels is in the ascendency mainly due to the accepted finite nature of fossils and their volatile price. The researcher is therefore definite that seeking to increase ethanol production and use ought to be vigorously pursued in Malawi.

The next section is a summary of the literature reviwed in light of the research objectives. Table 2.20 is an overview of the principal literature consulted.

2.20 Summary

The first research objective is to "*Determine the level of awareness on biofuel policy and strategy*". Literature reviewed shows successful biofuel regimes being directed by explicit biofuel policy and clear strategy. The implication is that implementing agencies were fully aware of extant biofuel policy and strategy. Table 2.14 summarises the emergent themes. In this research the level of awareness for Malawi is tested. .

The second research objective is to "*Find pathways of increasing ethanol production to make it significant in the liquid fuel portfolio"* various country cases reviewed presented pathways of how ethanol production volumes have been increased. This research will seek to find pathways for the Malawi context. .Table 2.14 shows the relevant themes.

The third research objective is to "*Find pathways for increasing the use of ethanol to make it significant in the liquid fuel portfolio".* The review of literature of the selected countries and regions reveals various tax incentives through relevant legislation to incentivize ethanol use. Pathways for increasing Malawi ethanol use are pivotal in this research.

The fourth research objective is to "*Investigate sustainability criteria for ethanol production and use*". Literature reviewed has brought to light the variety of sustainability criteria used and related themes presented in summary form in the Table 2.14. The sustainability of increased ethanol volume in the Malawi liquid fuels portfolio is also at the core of this research.

Table 2.20 Overview of principal literature review

Research Objective	Themes	Selected Authors	Finding	Conclusion
Objective a)	Consistent biofuels policy	Mitchell (2010); Jumbe *et al*.(2007); European Parliament Council (2009);	Required for investor confidence, Public awareness and consumer support.	Policy to coordinate biofuels and fossils required
Objective a)	Energy policy	Department of Energy Affairs, (2003); Khanje (2012); Chirembo (2012); European Parliamnt Council (2009); Oettinger (2012)	Lack of biofuel policy in Malawi. to blending ratios.	Biofuels policy to be embedded in National Energy Policy

Objective b)	Ethanol production incentives	Er (2011); Mitchell (2010); European Parliament, Council (2009);	Government to provide incentives for ethanol production. Incentives to be eventually removed when private sector convinced.	
Objective b)	Ethanol price	Shinoj et al.(2011); Er (2011); Mitchell (2010); Extra Ordinary Gazette, 31 December, 2010.	Ethanol pricing versus petrol to increase uptake.	Is a tool for increasing ethanol production and use.
Objective b)	Feed stock	Mitchell (2010); Chaudhari (2008); European Parliament Council (2009); Balat (2008)	More and diverse feed stock for ethanol production to increase volumes and uptake.	Viable strategy to increase ethanol production.
Objective b)	Sugar cane yields and land under sugarcane.	Shinoj et al. (2011); SADC Sugar Digest (2014); Mitchell (2010); Chaudhari (2008); Government of Malawi (2011)	Research sugar cane yields in order to increase them and increase volume of	Pathway to increase ethanol volumes

			molasses.	
Objective b)	Government incentives	Mitchell (2010); Demibars (2008); Gondwe (2014); O'Kray and Wu (2010)	Suggested pathway to increase ethanol volumes	Start up strategy to be phased out over time.
Objective b)	Ethanol standards	European Parliament Council (2009); Mitchell (2010)	Consistency. Potential of standards as non-tariff barrier to trade with Africa recognized and assistance via aid is offered by EU.	Energy policy to include standards
Objective b)	Cross pollination across countries.	Mitchell (2010) SADC Sugar Digest, (2014)	To boost ethanol production and marketing opportunities	Encourage regional biofuel conferences
Objective c)	Ethanol blending with petrol.	NEP (2003); PIL (2011); Mitchell (2010); Department of Energy Affairs, (2003); National Energy Policy (2003); Balat (2008; 2009)	Mandatory blending legislated in 2010 to be part of liquid fuel portfolio in Malawi after 30	National Energy Policy needs to recognize ethanol as a fuel. Biofuels policy

			years of use. Phased approach if volumes short.	to allow phased blending approach.
Objective c)	E thanol blending with diesel	Sheehan *et al*. (1998); Raju *et al*. (2009); Chaudhari (2008); Demirbas (2007;2008); Löfvenberg, 2007	No ethanol blending with diesel.	Missed opportunity to be revived for Malawi. No African country blending ethanol with diesel yet.
Objective c)	Ethanol driven vehicle and Flexi-vehicles	Er (2011); NSCT (2011); Kambatata (2012); Mitchell (2010)	Creating demand for ethanol; Reducing fossil dependence; Reducing harmful emissions – climate change issue.	Successful Brazil strategy may be adapted elsewhere.
Objecive d)	Sustaina bility of biofuel productio n	Trines et.al (2006); Fumo (2009);Mitchell (2010); Swinbank (2009); Purchas and Hutchinson (2008); Barber et.al (2008); Shinoj et al. (2011); European Parliament, Council (2009); Kambatata (2012); Demirbas	• Topical areas:Fe edstock producti on to be part of economi c develop ment strategy.	Sustaina bility issues central to biofuels developm ent. Exclude food crops from biofuels or energy

		(2010); Allen (2012)	Encourage second generation feedstock production. EU to aid third world via aid in developing production. • Energy crop viability • Land use change (LUC) and indirect land use change • Climate change (also global warming)	production. Sugar molasses is not food so qualifies as feedstock.

			Safe effluent disposal to be taken into account.	
Objective d)	Ethanol strategic storage.	Nkomo (2009); Khanje (2012) Department of Energy Affairs, (2003); Robinson, (2009); Lea and Hanmer (2009)	NOCMA still does not have ethanol tanks in the plan.	Strategic storage to manage supply interrupti ons.
Objective d)	Energy security	Oettinger (2012); ADB (2010); Nkomo (2009); Ahmad *et al.* (2013); Crooks, (2013); Nkomo, (2009); Balat, (2008); Sheehan *et al*. (1998); Grubb (2011); Kaberuka (2013); Thurnstrom *et al*. (2013)	Peak oil issues; Fossils depleting and not renewable; Link between fuel storage and energy security;	Fossil oil depleting, biofuels a possible solution.
Objective d)	Biofuel advantage s particularly ethanol.	Low and Isserman (2009);Barber et al. (2008); Anh-Thu and West (2004) Mitchell (2010);	Advantages of ethanol have been proven. Brazil case in point.	Malawi needs a biofuels policy to manage advantages

Source: Author's analysis

This chapter has provided a critical discussion on the various literature reviews on energy, liquid fuels and biofuel frameworks from the selected countries and regions. The chapter however, noted some gaps in the literature based on the research problem. Some of the gaps highlighted in this chapter in section 2.7 are summarized as follows:

(a). the absence of a biofuels policy in the NEP

(b). the absence of a biofuels strategy in the NEP beyond the blend mandate.

(c). the public are largely unaware that Malawi fuel is blended sometimes and sometimes not.

(d). Lack of government support for ethanol production and use

(e). the NEP does not recognize biofuels as a partial solution to fossil fuel shortages.

(f). No strategic ethanol fuel storage tanks in Malawi.

(g). NEP suggests interventions to avert fuel energy crises for petroleum products only such as a fuel pipe line from the Indian ocean, and oil exploration.

Chapter three presents the research methodology which has been adopted to achieve the objectives of this study. The chapter outlines the research method, research paradigm, data collection and analysis which have been chosen to address the research questions and gaps within the literature.

Chapter 3

Research design and methodology

3.1 Introduction

Chapter 3 presents the research design, methodology and processes that guided the implementation of this research. The design of this research, as implied by Saunders et al., (2009) was meant to guide the research in answering the following overall question: “How can the production and use of ethanol be sustainably increased in order to reduce dependence on fossil fuels in Malawi?”

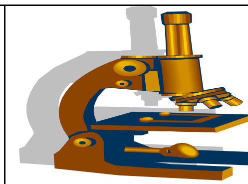
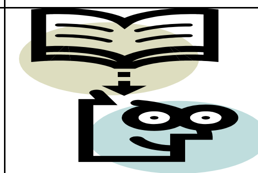
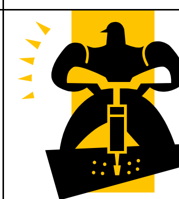
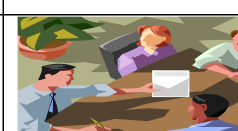
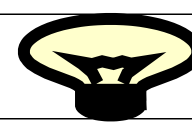
The research design was also meant to guide the researcher in answering the specific questions that are contained in Appendix 1 which are a synthesis of the initial questions in chapter 1 section 1.10 and questions from the literature review. All this was done in order to achieve the objectives of the research as defined in chapter 1 section 1.11. The literature review was conducted around each of the four research objectives.

The chapter begins by describing the research process then discusses the paradigm that was chosen for this research. It then proceeds to elaborate on approach, strategies and then sampling, qualitative and quantitative data generation, qualitative and quantitative data analysis. The chapter, therefore, discusses the mechanics of the research and provides a roadmap of how the research was implemented.

3.2 Research Process

Research is a logical step by step process to develop relevant statements that can explain a situation of concern (Creswell, 2009, p.7). The diagram in Figure 3.2 illustrates the motions and thoughts of this research.

Figure 3.2: Diagram of Research Stages

Formulation of research problem, objectives	
Literature review, Biofuel frameworks	
Research paradigm selection = Pragmatic	
Research Methods = face to face semi-structured interviews, questionnaire, archive search	
Data generation & analysis	
Research findings and discussion	
Framework	
Conclusion, further research	

Source: Author

The diagram summarises the activities that were undertaken in this research. The process began by a review of the initial literature, followed by a formulation of the research problem, objectives and questions. This was followed by a more intensive review of literature focusing on the objectives of the research. The objective was to understand the topic better and get views from others who had implemented similar research. The subsequent activity was research design including paradigm selection, approach and methodology selection, data generation and analysis. After this, the actual research came. The research was implemented using the specifcations in chapter three. A strategic framework was developed. Conclusions and the way forward followed.

Figure 3.2, therefore presents the road map of the research.
The next section introduces and discusses the research paradigm briefly.

3.3 Research Paradigm

There is no standard definition or agreement on the concept “paradigm”. Various scholars have defined and understood the concept differently. Vedanthachari (2007, p.59) quoting Hussey and Hussey (1997) says the term paradigm has been used quite loosely in academic research and can mean different things to different people. According to Kuhn (1970, p.35), a paradigm is “an accepted model or pattern” while Collis and Hussey (2009, p .55) describe a research paradigm as “a philosophical framework that guides how research should be conducted”. According to Creswell (2009), the philosophy one adopts depends on the beliefs the researcher holds about the world and the nature of research. There are, therefore, many shades or forms of paradigms or philosophies including the following: positivism, phenomenogy, constructivism, interpretivism and pragmatism. According to Saunders et al., (2009), two views dominate the literature about philosophy: positivism and phenomenology. Saunders et al., (2009) also notes that the two philosophies are not mutually exclusive but are complimentary.

The world view or research paradigm chosen for this research is pragmatism.

3.3.1 Pragmatism

Pragmatism is the world view or philosophy that the researcher chose because of its liberating stance in terms of straddling different paradigms and using what “works at the time” (Creswell, 2009, p.11). Pragmatism is, a philosophy or worldview that “arises out of actions, situations and consequences” (Creswell, 2009, p.10). Pragmatism advocates for the use of mixed methods, described in Section 3.5.1, in this research and it acknowledges that the values of the researcher play a large role in the interpretation of results (Vedanthachari, 2007). This supports the choice of this paradigm as the researcher’s subjectivity as a practitioner could not be excluded (Somekh and Lewin, 2005).

This research, therefore, was undertaken within the predisposition of "practitioner-based" research (Armitage, 2007). This approach has what Tashakkori and Teddlie (1998) and Creswell (2003) see as intuitive appeal, permission to study areas that are of interest, embracing methods that are appropriate and using findings in a positive manner. According to Creswell (2003), research of this nature is often multi-purpose and the "what works" tactic will allow the researcher to address questions that do not sit comfortably within a wholly quantitative or qualitative approach to design and methodology. The researcher was, therefore able to freely use different philosopies, paradigms, methods and appraoches because they worked for this research. Presented below are some examples and illustrations.

According to Creswell (2009, p.10) pragmatism is, a philosophy or worldview that "arises out of actions, situations and consequences". Taking advantage of this assertion, the researcher focused on the actions, situations and consequences in the energy sector in Malawi. For example, the action taken in 2005 in Malawi where the ethanol to petrol blending ratio was reduced to 10% according to CARD (2012) led ETHCO to migrate away from producing fuel ethanol (AA) to the production of ENA. One major consequence was that the volume available for blending dropped (Chapter 1, Figure 1.9.1). According to Kandadi (2006, p.25) "the epistemic nature of pragmatism is characterized by its insistence on consequences, utility and practicality". Currently, pragmatism is described as a deconstructive paradigm that debunks concepts such as "truth" and "reality" and focuses instead on "what works" as the truth regarding the research questions under investigation (Vedanthachari, 2007).

Pragmatism advocates for the use of mixed method, described in Section 3.5.1, in this research. As noted by Saunders et al., (2000, p.86), "Business and management research is often a mixture between qualitative and quantitative data". Qualitative research is associated with phenomenology while quantitative research is akin to positivism (Woll, 2013; Saunders et.al, 2009). This research was not wholly qualitative because the fourth objective regarding investigating sustainability implied the need to rank sustainability criteria once identified (Chapter 1, section 1.10). Questions regarding fossil fuel and ethanol volumes are also necessarily quantitative. The research was not wholly quantitative either because to achieve some of the objectives in chapter 1(section 1.10) open ended questions were asked such as how the production and use of ethanol can be increased or what role ethanol could play in the liquid fuel portfolio in Malawi. In support of this, Darlington and Scott (2002) noted that in reality a great number of decisions of whether to take a quantitative or qualitative research approach are based not on philosophical commitment but on belief of a design and methodology best suited to purpose.

The researcher used a positivistic approach seeking facts with little regard to the subjective state of the individual researcher (Hussey and Hussey, 1997). In this research quantitative data was collected an example being the volumes of ethanol produced and fossil (petroleum) fuel volumes imported. These volumes were used to show the relationship between fossil fuels and biofuels specifically petrol and fuel ethanol in the Malawi energy sector.

The researcher, for example, used elements of phenomenology. The assertion by Saunders et al*.,* (2000, p.86) that generalisability is not so important for a phenomenological study as reality is what it is resonates with pragmatism. In this research, the researcher was a player at various levels in the Malawi liquid fuels industry and experienced the reality which cannot necessarily be replicated. According to Saunders et al*.* (2000, p.86), generalisability is not critical due to "all organisations being unique". The Malawi energy sector described in section 3.6, has many unique organisations and findings may not allow generalizing. This agrees with the pragmatic view chosen for this research.

According to Rosenthal and Bourgeois (1980) pragmatism accepts that the researcher's perceptions have a bearing on reality. The reality in the context of this research is ethanol production and use and the researcher's perception is that a solution for fossil fuel outages and eventual fossil resource depletion lies partly with biofuels specifically fuel ethanol (AA). The following statement by Rosenthal and Bourgeois (1980, p.54) "For in the life-world all is temporal and incomplete" is demonstrated by the 2005 change of the Malawi ethanol to petrol blend ratio to 10% down from 20% and back to 20% in 2010 meaning that the relationship between fuel ethanol and petrol can change anytime and is therefore "temporal" (Chapter 1, section 1.9).

According to Kandadi (2006, p.29), pragmatism rejects the view that reality is represented by human concepts and intellect, and holds that it is only in the struggle of intelligent organisms with the environment and surroundings that theories and data acquire significance. Pragmatism solves certain problems constrained by both the world and human machinations (Kandadi, 2006). An example of data acquiring significance is given by CARD (2012) where he states that political pressure acted to prevent ETHCO from completely abandoning fuel ethanol production in the national interest against the profitable interests of ETHCO in that situation. One result of the "struggle of intelligent organisms" with the political and economic "environment" is the lower volumes of fuel ethanol produced at ETHCO over the years leading to the main issue of not producing enough ethanol to meet the blend mandate (Chapter 1, section 1.6, Figure 1.6, section 1.9).

The researcher considered achieving the research objectives as paramount and reviewed literature for each objective accordingly. The analysis sections under each objective in the literature review were related to the research questions (Chapter 2, sections 2.13.1; 2.14.6; 2.15.6; 2.16.6). This highlighted the research questions which led to the development of the research instrument, the semi-structured questionnaire. According to Saunders et al. (2000), the use of a questionnaire (or survey) is a popular and common strategy in business and management research. Much valuable information can be collected which is easily understood. The downside of this strategy is that time has to be taken to pilot the questionnaire. In this research the questionnaire was piloted where energy strategists from diverse organisations involved in energy production, regulation, standards, research and policy were interviewed. As indicated earlier the research instriument was then reviewed (Chapter 1, section 1.10).

The questionnaire had a quantitative section designed to deal with sustainability criteria. According to Creswell (2009, P.3) "quantitative and qualitative approaches should not be viewed as polar opposites or dichotomies, rather they are different ends of a continuum".

Creswell (2009) summarises the advantages of using the pragmatist worldview:

a) Pragmatism is not committed to any one system of philosophy and reality. Pragmatist draw without limits from both quantitative and qualitative assumptions in their research.

b) Researchers are free to choose the methods, techniques and procedures that best meet the needs of their research.

c) For pragmatists, the world has many realities. As such there are many ways for conducting research including mixed methods.

d) Truth is what works at that time.

e) Pragmatists look at the what and the how to research based on the intended consequences.

f) Research always occurs in social, historical, political and other contexts.

In the next section the research approach is discussed.

3.4 Research Approach

The design of the research is determined by the extent to which one is clear about the use of theory in the research (Saunders et.al, 2000). This determines whether or not the researcher should use a deductive or inductive approach. The deductive method is used where the researcher develops theory and hypothesis and design a research strategy to test the hypothesis. The inductive method isused where the researcher collects data to build a theory and hypothesis. The deductive approach is akin to the positivist paradigm while the inductive approach is closely related to phenomenology.

An inductive approach is concerned with the “context in which… events were taking place” (Saunders *et al.,* 2000, p.89). As already pointed out this approach is akin to phenomenology. However phenomenology was not employed in this research due to its twin demands of generalizability and objectivity (Section 3.3). The Malawi liquid fuels contextual setting leaned the research towards the inductive approach. In section 3.5 it is explained that to answer the research questions both quantitative and qualitative data was used. The quantitative portion is largely related to the question of sustainability. It is advantageous to combine the deductive and inductive approaches (Creswell, 2009). Section 3.5.8 explains the advantages of using qualitative and quantitative methods in the same research. This is consistent with the pragmatic philosophy which was adopted for this research.

Table 3.4 summarises the major differences between the deductive and inductive approaches to research. The approaches are also referred to as research methodologies (Creswell, 2009).

Table 3.4 Major differences between deductive and inductive approaches

Deduction	Induction
Scientific principles	Gaining an understanding of the meanings humans attach to events
Moving from theory to data	
The need to explain causal relationships between variables	A close understanding of the research context
The collection of quantitative data	The collection of qualitative data
The application of controls to ensure validity of data	A more flexible structure to permit changes of research emphasis as the research progresses
The operationalisation of concepts to ensure clarity of definition	
A highly structured approach	
Researcher independence of what is being researched	A realization that the researcher is part of the research process
The necessity to select samples of sufficient size in order to generalize conclusions	Less concern with the need to generalize

Source: Saunders et al. (2000, p.91)

Following the choice of a research approach the research methodology is now discussed. The next section details the methodology used for the research.

3.5 Research Methods

Taylor and Bogdan, (1998, p.3) refer to methodology as the systematic procedure for collecting empirical information. They further point out that “the term methodology refers to the way in which we approach problems and seek answers”. Defined this way, there are various methodologies that exist and different methodologies can be used for a given ontological or epistemological perspective (Vedanthachari, 2007). This means that the choice of research methodology is based on the researcher’s objective, it could be discovering new truth based on the hypothesis put forward or to explore and unpick people’s multiple perspectives in natural field settings (Gray, 2004).

In this section, the instrument used for qualitative and quantitative data collection is described followed by a description of the mechanics of the process (Figure 3.2). The data collection instrument was developed based on the initial research questions in chapter 1 section 1.10, the knowledge gained in the literature review in chapter two and other sources such a conferences, seminars and meetings attended. The overall objective of the research was to develop a strategic framework for sustainably promoting ethanol production to make ethanol a significant part of the liquid fuels portfolio and reduce fossil fuel dependence in Malawi. The design of the instrument reflects the following specific objectives to:

a) Determine the level of awareness on biofuel policy and strategy.
b) Find pathways of increasing ethanol production to make it significant in the liquid fuel portfolio.
c) Find pathways for increasing the use of ethanol to make it significant in the liquid fuel portfolio.
d) Investigate sustainability criteria for ethanol production and use.

The following were the main research questions:

a) What policies exist to coordinate bio-fuels and fossil fuels?
b) What should be done to make ethanol more significant in the Malawi liquid fuels portfolio?
c) How can the use of ethanol be increased?
d) What criteria should be considered in determining biofuel sustainability?

The instrument that was developed sought to answer the questions and in so doing achieve the objectives. Appendix 1 contains the instrument. After designing the instrument it was tested for its reliability to collect accurate and reliable data. Having passed the test, the data collection instrument was used as described in the paragraphs that follow. Qualitative data collection and quantitative data collection was done concurrently. According to Creswell (2009, p.14) a concurrent mixed method comprises of the whole or a portion of the study using both qualitative and quantitative data collection methods and interrogates the information in the interpretation of the overall results. The following section discusses mixed methodologies.

3.5.1 Mixed methodologies

Consistent with the pragmatic world view that this research adopted, the researcher was at liberty to use both qualitative and quantitative methods or in deed any other method deemed appropriate by the researcher. The archival search is explained first in the paragraphs that follow. This is followed by attendance in conferences, seminars and meetings. The concurrent mixed approach whereby the researcher used both qualitative and quantitative methods then followed.

According to Maanen (1983, p.9), “Qualitative technique is an array of interpretative techniques which seek to describe, decode, translate and otherwise come to terms with the meaning, not the frequency, of certain more or less naturally occurring phenomena in the social world”. Data gathered through qualitative research would be predominantly textual in nature and it is difficult to standardise the findings. While the main aim of quantitative research is to determine the relationship between one thing (an independent variable) and another (a dependent or outcome variable) in a population. Quantitative research designs are usually objective (subjects usually measured once) or experimental (subjects measured before and after treatment) (Hopkins, 2000). The research results are given in numerical values and the researcher uses mathematical and statistical methods to evaluate the results. The results emanating from quantitative research can be generalised.

Irrespective of the researcher's objective, the entire research process can be classified as mixed with qualitative research being dominant with a very minor supporting quantitative research. When elements of both the qualitative and quantitative are used in the same research the term mixed research is used (Collis and Hussey, 2003). The next section presents how the archival, qualitative and quantitative methods were used.

3.5.2 Archival search

Archival searches in ethanol company documents and government agencies established trends and volumes of imported liquid fuels in Malawi and ethanol produced locally over the years. The document searches also included current legislation on liquid fuels in general and ethanol in particular. Research based largely on documentary secondary data is called archival research (Saunders et al., 2000). In this research a large number of company documents and meeting documents were accessed on the basis that the researcher was a practitioner in the liquid fuels energy sector, was a member of the biofuels association of Malawi and board member of ethanol producing companies. This status also afforded access to minutes of relevant government meeting minutes. Documents on line from government ministries and departments such as the National Statistics Office, Reserve Bank of Malawi, Department of Energy, Ministry of Energy, MERA and MRA also provided valuable information (Table 3.5.2).

Table 3.5.2 Summary of principal documents accessed

DOCUMENT	SOURCE
Government gazettes	Ministry of Energy
National Energy Policy	Department of Energy Affairs. Malawi Government.
Green Belt Initiative	Malawi Government [online]
Policy Notes	Malawi Strategy Support Programme Malawi Government [online]
Fuel Price Build up	MERA
Biomass Energy Strategy for Malawi	Malawi Government

Board Minutes	ETHCO
Board Minutes	PressCane Ltd
Audited Accounts – PressCane Ltd 2004 to 2013	Deloitte
Letter – opening of biofuel facility	Bio Energy Resources Ltd
EDVP Reports	NSTC
National Statistics Reports	NSO [online]
Economic & Annual Reports	Reserve Bank of Malawi (online)
Meeting Minutes	Association of Biofuels Malawi
Report on National Policies and Strategies.	Jumbe et al. [online]
Meeting Minutes	MERA
MERA Strategic Plan Meeting Minutes	MERA
Maputo Conference Presentation (2010) – Malawi Ethanol Industry	Kacelenga
Shire Valley Cane Growers Meeting Minutes.	PressCane Ltd
Letter – GBI Sugar Project Salima	Malawi Government Chief Secretary
Report on ethanol blend and unleaded petrol.	Department of Energy Affairs
State of the Nation Address by the President of Malawi.	State House [online].
Malawi Development Growth Strategy (2006 – 2011)	Malawi Government [online]
News on oil, land disputes, fuel reserves, anti-smoking lobby, Illovo Sugar winter cropping, Shire-Zambezi Waterway, Lessons from Malawi's Food Crisis	DAILY TIMES and THE NATION newspapers and online.

Source: Author

3.5.3 Conferences, Workshops and Meetings

The researcher attended World Biofuels conferences annually for ten years in Brussels and Amsterdam with an average of over 100 participants per day. In addition the researcher attended Africa Bio-fuels conferences in Maputo Mozambique, Cape Town, and Nairobi. These conferences and workshops provided information on a variety of biofuel issues including sustainability issues, feedstocks, ethanol processing technology and waste management, LUC and ILUC perspectives, climate change issues and ethanol markets activities.

The researcher also attended regular meetings at MERA in his capacity as head of one of the ethanol companies. All PIL member companies purchase their ethanol from the two ethanol companies for the mandatory blending programme with petrol. The researcher also sat on the board of the other ethanol company as both companies have the same majority shareholder (Press Corporation Limited). The two ethanol companies are members of the Biofuels Association and therefore have access to minutes of meetings. Given this set of circumstances the sample population covers all organisations in the liquid fuels sector in Malawi and all the policy and decision makers. A number of unstructured interviews were conducted before and after the semi-structured interviews to clarify certain answers. The unstructured interviews were informal with no predetermined list of questions (Saunders et. al., 2000).

3.5.4 Qualitative Data Gathering

Qualitative data gathering was mainly done through the one on one face to face semi-structured interview. The researcher made appointments by phone and explained the purpose of the interviews. Upon agreeing an appointment was firmed. The problem in some cases, however, is that in spite of having confirmed an appointment; some of the target audience did not honour it thus necessitating another appointment. This was the experience of the researcher with four appointments. For some appointments, the researcher had to wait much longer after the appointed time. The researcher did not give up until the appointment was realized.

The researcher started the interviews by introducing himself and the reason why he was conducting the interviews. He went further to explain how the interviews would be conducted and issues to do with ethics. He explained that he would not disclose the identity of the respondent nor mention his name anywhere in the document. He also sought permission to record the interview digitally and manually by writing. Permission was granted by all so the questions and answers during the semi-structured face to face interviews were recorded digitally using a dictaphone. The IPad and smart phone proved to be more convenient as the recordings were easily transferred and stored on the laptop unlike the dictaphone. Only one gadget was used at a time although both were present for backup purposes in case one malfunctioned as happened with the dictaphone. Taking notes manually in writing was very limited as it tended to interfere with the researcher's listening. In the semi-structured interviews the researcher sought the views of energy strategists on sustainability and pathways for increasing ethanol production.

The length of interviews varied a great deal from one and a half hours to over two hours reflecting the variety of the targeted energy organisations (section 3.6).

Both the quantitative and qualitative approaches were used concurrently to generate data. The largely qualitative questionnaire had quantitative questions embedded (Appendix I). The mixed data generation strategy used in this research was therefore consistent with the chosen pragmatic paradigm as described in section 3.3 (Saunders *et al*., 2000).

3.5.5 Qualitative Data Analysis

The qualitative data generated from the recorded semi-structured interviews was transcribed into a table structured according to the objectives and themes. The recordings on the IPad and smart phone were played back for many hours and for each question the responses were written out by hand (transcribed). The responses were analysed and grouped into themes. The themes from the literature reviewed shown in Chapter 2 (section 2.20) were used to guide the process together with the objectives of the research. Incomplete information was omitted and the common patterns and themes between the gathered data were compiled. Hair et al, (2007) quoted by Salimi and Kandadi (2009) states that the objective of qualitative data analysis is to identify, examine, compare and interpret patterns and themes. The four objectives of the research were, therefore, broken down into a series of questions each targeting a particular theme (Appendix 1). According to Saunders et al., (2000, p.243), the researcher had a list of themes and questions. Additionally some questions were omitted during the interviews depending on the organisational context. For example questions about volumes of imported fossil fuels were not asked of some interviewees in this research such as the hydro generation energy experts who are not directly in the liquid fuels energy sector.

The themes investigated are shown in Table 3.5.5 in relation to the objectives of the study. As the research progressed other themes emerged such as strategic fuel storage and synergies between ethanol and fossil fuels. The thematic analysis was consistent with literature (Saunders et al., 2009; Salimi and Kandadi, 2009).

Table 3.5.5 Themes relative to objectives

Objective a)	**Objective b)**	**Objective c)**	**Objective d)**
Public awareness of ethanol	Pathways for increasing ethanol production volumes.	Pathways for increasing ethanol use	Ethanol Sustainability criteria
Policy: biofuels inclusion in energy policy.	Role of ethanol	Blend mandates and legislation.	Energy crop viability
	Feed stock	Price controls and levies	ILUC & LUC
	Government incentives for ethanol production	Government initiatives on ethanol use.	Benefits of ethanol

Source: Author's analysis

3.5.6 Quantitative data collection.

Quantitative data was collected concurrently with the qualitative data. The same questionnaire was used. In section one were qualitative questions and in part two were quantitative questions. The researcher went through all the qualitative questions with the person being interviewed and asked the interviewee to complete the quantitative part in the researcher's presence making it self-administered as explained by Sankhulani (2007).

The quantitative questions required the interviewees to rate sustainability criteria in order to establish the relevant ones for Malawi. From literature reviewed in chapter two section 2.17.1. The researcher established that there a many sustainability criterion which apply differently to different countries and economies. Some economies such as the EU and Brazil emphasize on GHGs while others such as India place emphasis on rural development (Chapter 2, section 2.17). The quantitative portion of the questionnaire had a Likert type scale for establishing the relevance of each sustainability criterion ranging from 1 to 5 (Appendix II) where 1 meant *Not relevant at all*, 2 meant *Mostly not relevant*, 3 meant *Neither relevant nor irrelevant*, 4 meant *Mostly relevant* while 5 meant *Absolutely relevant*. The objective of the quantitative data collection was to obtain perceptions of the respondents on sustainability criteria which are important to Malawi.

3.5.7 Quantitative data analysis

The quantitative data analysis involved manually counting the number of responses for each criterion to determine how each was rated. The interviewees rated each criterion for relevance. There were seventeen criteria which were rated. The researcher took these ratings and constructed a frequency graph (Figure 4.5.2) using excel to determine which criteria were most frequently viewed as important based upon the ratings.

3.5.8 Advantages of mixed methods

As already explained in section 3.5.1, the mixed method was chosen firstly because it allowed the researcher to deal with a variety of institutions and organisations such as regulatory authorities, government departments, biofuel producers, and fuel importers in the liquid fuels sector. A wholly qualitative or quantitative approach would not provide deeper insights (Collis and Hussey, 2003).

Secondly, according to Saunders et.al. (2000), it is beneficial to use multi method approaches because you can triangulate the results as explained in the paragraphs that follow. Thirdly, as explained fully in section 3.5 the objectives of the current research do not all sit comfortably within a wholly quantitative or qualitative approach (Creswell 2003).

The use of different methods, techniques and approaches in research is called triangulation (Collis and Hussey, 2003). Easterby-Smith et al., (1991) identifies four types of triangulation as follows:

a) **data triangulation**, where data is collected at different times or from different sources in the study of a phenomenon.
b) **investigator triangulation**, where different researchers independently collect data on the same phenomenon and compare the results.
c) **methodological triangulation**, where both quantitative and qualitative methods of data collection are used.
d) **triangulation of theories**, where a theory is taken from one discipline (for example, marketing) and used to explain a phenomenon in another discipline (for example, accounting).

Data triangulation was used in this research. This was done because interviews of the various respondents in the liquid fuels sector were conducted at different times and data was sourced from multiple sources as described in sections 3.5.2 to 3.5.7 (Easterby-Smith et al., 1991). This included interviewing more than one senior person in the same organization.

Jick (1991) argues that triangulation has vital strengths, as it;

a) encourages productive research,
b) enhances qualitative methods and
c) allows the complementary use of quantitative methods.

The weaknesses of triangulation are that, replication is difficult to perform where a mixed method approach is used, particularly where qualitative data is generated. Furthermore, data collection and analysis is time consuming and expensive. Woll (2013, p.1) agrees that although interviews and observational techniques are well known and accepted ways of data collection “particularly in in-depth qualitative phenomenological research” they are often time consuming and expensive.

3.6 Purposive sampling

There are thirteen organisations regulated by MERA in the liquids fuel sector in Malawi (Chapter 1, Figure 1.8). The researcher targeted for interviews people from these organisations involved with energy and specifically those in the liquid fuels as opposed to interviewing people from all organisations in Malawi. Further, only senior people including: Chief Executive Officers, directors and senior managers were interviewed. This is called purposive sampling as opposed to random sampling where each organisation (or individual) in a population has an equal probability of being selected for interviews (Creswell, 2009, p.148). Purposive sampling is also called judgemental sampling by Saunders *et al.*,(2000) because the researcher makes a judgement as to whom to interview.

The people targeted for interviews as already alluded, were those of the rank of head of department, directors, deputy director, Chief Executive Officers, Permanent Secretaries and board directors (past and serving) in large energy corporates or central government departments dealing with energy matters. Saunders et al., (2000, p.153) says for populations of “less than 50 cases” data should be collected “on the entire population” so that no single extreme case can influence subsequent statistical analyses. However, only thirty three senior managers (policy makers) in those thirteen organisations were targeted and successfully interviewed. All appointments were set up via telephone and all interviews were conducted in person. This is consistent with Saunders et al., (2000, p.174) “because they are important”. As Denzin and Lincoln (2000) put it “Many qualitative researchers employ purposive and not random sampling methods. They seek out groups, settings and individuals where … the processes being studied are most likely to occur”.

The thirteen targeted energy related organisations, which form the liquid fuels sector in Malawi as described before, with the three non-fuel organisation, were as follows:

a) MERA: because it is the energy sector regulator responsible for licensing, fuel pricing and blend compliance inspections. Semi-structured interviews (face to face interviews) were conducted concurrently with a self-administered questionnaire. In all six key personnel were consulted, among them the CEO, a former CEO, three heads of department and an acting CEO. The technical head of department was engaged with several times.

b) Department of Energy Affairs (DoEA) –This was targeted for consultations because it is the custodian of policy on energy. The following are some key roles and responsibilities: improving energy sector governance, increasing access to energy, improving efficiency and effectiveness in energy supply.

   In this Department the researcher interviewed one of the Directors four times including attending a conference on bio-fuels in Amsterdam together. The objectives of interviewing this officer was to obtain clarity between the roles of MERA and DoEA, seek DoEA‘s position on ethanol pricing, strategic storage and biofuels development. A face to face semi-structured interview was conducted concurrently with the self-administered questionnaire. The Department of Energy Affairs actually spawned MERA consequently in many respects the Department overlaps with MERA (Department Of Energy Affairs, 2003; MERA, 2008) particularly in fuel pricing.

c) Petroleum Importers Limited (PIL) was targeted for interviews because it is a company owned by all five oil marketing companies in Malawi. The oil marketing companies are the main customers for fuel ethanol due to the blending mandate (Extra Ordinary Gazette, 31st December, 2010). The targeting of PIL for interviews is thus justified. Three senior officers, including a CEO and a former CEO were targeted for face to face semi structured interviews.

d) Ethanol Company Limited (ETHCO) was chosen because it is the first bio-fuel company in Malawi. It was established in 1982 with a capacity of 60,000 litres per day. The normal season is six months a year due to the raw material, molasses, being available only when the Illovo sugar mill in Dwangwa is running. The researcher conducted face to face semi-structured interviews concurrently with a self-administered questionnaire with two senior officers .

e) PressCane Limited – this is the second ethanol producing company. It was established in 2001 but began operations in 2004. The plant rating is 60,000 litres per day. Molasses is the raw material supplied by the Nchalo Illovo Sugar Mill. The sugar mill operates six months a year consequently molasses is available for only six months a year. At the time of this research, the researcher was working as CEO for PressCane Limited. Four senior members of management were consulted as well as a Board Director.

f) Bio Energy Resources Limited (BERL) was chosen because it is a private company engaged in bio-fuel production. It was established in 2006 (Chittock, 2012). Specifically, the company is promoting the planting of jatropha in readiness for producing bio-diesel from jatropha oil as a bio fuel. At the time of the interview the biodiesel from jatropha had not yet been approved by MERA, pending approval by the Malawi Bureau of Standards (MBS) (Lane, 2012). Three senior officers, in the new jatropha oil company were consulted and interviewed face to face.

g) The Biofuels Association was formed in 2012. The initial membership was three with one Biofuel Company, a farmers' organisation and an environment organisation (Biofuel Association, 2012). The Association accommodates all bio fuel industries, farmers' organisations, government officials and industries working with a range of feedstocks (Biofuel Association, 2012).

   The objectives of the Biofuels Associations are to promote the production, distribution, sale and consumption of biofuels in Malawi. Supporting research and development in biofuels in order to improve the industry is another objective. The third objective is the reduction of the unit cost of production for players in the bio fuel supply chain. Dissemination of information to, from and between its members and other stakeholders is the fourth objective. The final objective is to promote the interests of its members amongst non-affiliated, non-government and government institutions.

   The researcher interviewed one senior official (the Secretary General at the time) face to face and self-administered the quantitative questionnaire at the same time (concurrently).

h) Ministry of Energy and Natural Resources was targeted because it is the parent Ministry of the energy sector. It is responsible for policy and has oversight of the national energy developments. In all two senior officers (Permanent Secretaries at the time) were interviewed, face to face.

i) The largest alternative energy organization in Malawi is ESCOM. This organisation was targeted because it too is regulated by MERA and the pricing regime applied is similar to that used for liquid fuels. Two senior officers including the CEO then and an acting CEO (Head of Distribution) were interviewed face to face and concurrently a quantitative questionnaire was self-administered.

j) A face to face interview was conducted with a Senior officer (also a former CEO of PIL) of the National Oil Company of Malawi (NOCMA) a government strategic liquid fuel storage company recently set up (Khanje, 2012). NOCMA was targeted in order to interrogate strategic fuel and ethanol storage issues in the energy context.

k) LUBE MASTERS was targeted for interview because it is an OMC outside the PIL grouping. One top officer (former CEO of ETHCO) was interviewed face to face and concurrently administered a questionnaire during the interview.

l) A researcher and one director for EDVP at the National Commission for Science and Technology were consulted and interviewed face to face. The choice for interview was due to their role in this project which started in 2006 and was concluded in 2011 (NCST, 2011).

m) A questionnaire was sent by email to two senior officers of MBS and responses were received. MBS was targeted because it is the standards body that approves product standards including liquid fuels in general and ethanol in particular. In all two senior officers were consulted.

n) Kasinthula Cane Growers Limited (KCGL) in Chikwawa provided valuable information on sugarcane feedstock during face to face semi-structured interviews. KCGL was targeted because all the sugarcane is sold to Illovo and PressCane was exploring how to obtain extra feedstock from KCGL and elsewhere for ethanol production (Mndolo, 2013). Several meetings were held with senior members of management (including the CEO) (Mkhomaanthu, 2013). In all four people were consulted.

3.7 Ethical considerations

To maintain ethical standards of research Salimi and Kandadi (2009) suggest keeping the details of respondents and their organisations separate from the analysis and conclusions. The privacy of the respondents was thus observed by the author by oblique references to officers in the various organisations. Stake (2000) supports this by stating that "qualitative researchers are guests in the private spaces of the world. Their manner should be good and their code of ethics strict." Many authors point out that ethical issues must be considered in the course of research (Saunders et al., 2009; Stake, 2000; Kandadi, 2009; Vedanthachari, 2007).

The salient aspects in the context of this study are highlighted given that the collection of data was through face to face semi-structured interviews. The following ethical protocols were followed in keeping with the ethical practice standards alluded to throughout the research:

a) The names of the organizations have been separated from the respondents and are not identified with the respondents.

b) The names of the respondents were deliberately separated from the analysis and conclusions.

c) Data accuracy was ensured at various stages of this study using triangulation For example former CEOs of some organisations were interviewed as well as more than one Head of Department in one organisation. Another example is the numerical data for fuel imports which was obtained from three sources, PIL, MERA and NSO.

d) Consent of the respondents for the interviews and recording was obtained in person. Further, where necessary, before publishing the works based on the study, consent will also be obtained from the targeted organizations and respondents.

e) The empirical material was safeguarded during this research and will also be safeguarded in future in order to protect the privacy of the respondents and their organizations.

As a consequence the exact respondents' names and their positions in the organisations mentioned in section 3.6 are not stated. As already stated consent for interviews and recording of the same was sought in person by the researcher from each interviewee.

3.8 Validity and Reliability

Issues of reliability, validity and generalisability were given due consideration for the primary and secondary research methods. The number of corporate energy related organisations involved in this research is thirteen energy and one small holder sugarcane growing organisation not directly related to energy (section 3.6). However the number of people interviewed was over thirty three plus those met in conferences. As mentioned in this chapter section 3.6, to buttress the validity of the findings, generally more than one individual per organisation was interviewed. For example six people were interviewed at MERA including the CEO and a former CEO. Further others were interviewed more than once in order to clarify earlier responses as in the case with the Department of Energy (DOE).

While reliability refers to issues of repeatability, according to by Saunders et al., (2000, p.251) non-standardised research methods may not be repeatable, but the findings represent reality. In pragmatism according to Creswell (2009, p.11)"truth is what works at the time". The hallmark for qualitative research is "particularity" rather than "generalizability" (Creswell, 2009). The uniqueness of the organisations in the liquid fuels industry which includes a regulator, ethanol producers, fuel distributors, research institutions to name a few find relevance here (section 3.6).

According to Collis (2003), reliability also has to do with issues of credibility. Another aspect of reliability is whether the evidence or conclusions drawn will stand up to scrutiny (Raimond, 1993). Before and during the research the researcher attended several annual conferences on biofuels and this afforded the opportunity to check the reliability of the findings. Some organisations such as MERA and DOE were visited several times to clarify certain responses thus enhancing the reliability of the data collected (section 3.6). Given the complex and dynamic reality of the ethanol industry in Malawi and the liquid fuels sector as shown in the background above, adopting the pragmatist stance could be justified. The pragmatist researcher according to Creswell (2009, p.11), looks at the "what and how to research based on the consequences – where they want to go with it".

Triangulation is the use of different methods, techniques and approaches in research (Collis and Hussey, 2003). In this research data collected from different organizations at different times and from other sources such as government and company documents was triangulated (section 3.5.8). Methodological triangulation was also employed as both qualitative data and quantitative data was collected concurrently for part of the research. This resonates with the chosen mixed method which aligns well with pragmatism as multiple methods are permitted (Creswell, 2009). According to Jick (1991) triangulation has vital strengths, as it allows the complimentary use of quantitative methods in a qualitative study thus enhancing the validity of the study among other advantages.

3.9 Summary

This chapter covers the design and mechanics of the research processes and presents understanding of the concepts paradigm, approach and methodlogy.The pragmatic paradigm was chosen because of its flexibility.The approach chosen for the research is largely inductive and the methodology selected is mixed consistent with the pragmatic paradigm. The research instrument was primarily the semi-structured interview concurent with a quantitative questionnare. Support research instruments selected were the archival search and unstructured interviews. Table 3.9 highlights (in yellow, bold and italicised) the major selected research tactics used.

Table 3.9 Summary of research methodology

Paradigm	Approach	Strategy	Methodology	Data collection
Critical	***INDUCTIVE***	Experiment	Mono method	***INTERVIEWS***
Interpretivist	**DEDUCTIVE**	***SURVEY***	***MIXED METHOD***	***ARCHIVAL SEARCH***
Positivism		Case study		***QUESTIONNAIRE***
PRAGMATISM		Action research		
		Grounded theory		
		Archival research		
		Ethnography		

Source: Author

As shown in Table 3.9 pragmatism was the chosen paradigm while the approach was mainly inductive.

Chapter four presents the findings, the analysis of the data collected and discussions.

Chapter 4

Research Findings and Discussion

4.1 Introduction

In chapter four research findings are presented and discussed in relation to each one of the objectives in the order they are presented as follows:

a) Determine the level of awareness on biofuel policy and strategy.
b) Find pathways of increasing ethanol production to make it significant in the liquid fuel portfolio.
c) Find pathways for increasing the use of ethanol to make it significant in the liquid fuel portfolio.
d) Investigate sustainability criteria for ethanol production and use.

In order to interrogate and examine these objectives, the researcher posed some key research questions. Some thirteen corporate energy organisations and central government departments were identified and targeted for consultations in order to answer these questions (Chapter 3, section 3.8). The reasons for selecting them were given in Chapter 3, section 3.8. A total of thirty three officers were consulted in face to face interviews. The objective was to obtain considered factual opinions on the objectives of this study. Concurrent methodology was used consistent with the pragmatic approach chosen (Chapter 3, section 3.5, 3.7.). Qualitative data was generated through semi-structured interviews in face to face interviews with respondents from the thirteen corporate energy sector organisations. The key qualitative questions in Appendix I were in four categories designed to respond to the objectives. The following were the research questions:

a) What policies exist to coordinate bio-fuels and fossil fuels?
b) What should be done to make ethanol more significant in the Malawi liquid fuels portfolio?
c) How can the use of ethanol be increased?
d) What criteria should be considered in determining biofuel sustainability?

A self-administered quantitative questionnaire (Appendix II) was administered to the same target audience concurrently with the semi-structured interviews. This questionnaire probed issues of sustainability criteria discussed in section 4.5. The objective was to obtain the perceptions of the target audience regarding sustainability. The questionnaire had a Likert type scale for establishing the relevance of each sustainability criterion ranging from 1 to 5 (Appendix II). The ratings were as follows:

a) Not relevant at all
b) Mostly not relevant
c) Neither relevant nor irrelevant
d) Mostly relevant
e) Absolutely relevant

A thematic analysis as described in chapter 3 section 3.7.5 was done to draw out themes from the semi-structured interviews which were recorded and transcribed and from the self-administered quantitative questionnaires on sustainability. This method confirms what Creswell (2003) said, that research is often multi-purpose and a "what works" tactic will allow the researcher to address questions that do not sit comfortably within a wholly quantitative or qualitative approach to design and methodology. This research was, therefore, predominantly qualitative and the quantitative information drawn from the concurrently self-administered questionnaire was used to enhance the qualitative analysis. The findings of the research are presented and discussed under each objective in the paragraphs that follow.

4.2 Objective a): Determine the level of awareness on biofuels policy and strategy

Awareness of policy is important. People support policies because they are aware of the policy. Awareness is knowledge or consciousness of the policy and strategy in question (Swannel, 1992). In this section the level of awareness on biofuels policy and strategy was investigated, because consumers support must be secured to achieve a successful biofuels regime (Mitchell, 2010). The findings pertaining to awareness on biofuels are presented in the paragraphs that follow.

4.2.1 Awareness of Biofuels Policy

The respondents from the thirteen corporate energy organisations and central government departments were asked a question during the face to face interviews using a semi-structured questionnaire as to "whether they are aware that there is a policy to coordinate biofuels and fossil fuels?" The responses were unanimous in that thirty three out of the thirty three (100%) respondents from the thirteen corporate energy organisations and central government departments said they were not aware of the existence of a policy to coordinate biofuels and fossils. They were quick to point out that they were, however, aware of ethanol use in blending with petrol as regulated by MERA (Extra Ordinary Gazette, 31st December, 2010). The responses recorded in this section confirm that there is no officially documented policy for coordinating biofuels and fossils. The NEP mentions ethanol but not biofuels as follows:

> *"Malawi imports 97% of its refined petroleum, the balance is contributed by locally produced ethanol, sold directly to the oil companies for blending with petrol on a maximum 20:80 ratio of ethanol-petrol ……nearly 7% of the total liquid fuels market". (Department of Energy Affairs, 2003, p.73).*

As highlighted in Chapter 1 section 1.7 this extract from NEP is the only place where ethanol is mentioned in the context of blending with petrol. No biofuels are mentioned in the NEP. The blending mandate in the Gazette of 2010 deals specifically with the blending of petrol with ethanol. The extract from the NEP remains largely unaltered which is part of the reason this research is being undertaken.

The implications of the absence of a biofuels policy have been discussed in chapter 2 section 2.7. Efforts to achieve an optimal liquid fuels portfolio are stymied because there is no policy to coordinate biofuels and fossils. This is evidenced by how government ministers and senior officers react to fossil fuel shortages, usually scapegoating ethanol and side stepping the real issues in the supply chain such as forex shortages and logistics (Kambatata, 2012). This dissonance is actually embedded in the NEP as already explained in Chapter 2 section 2.7 (Department of Energy Affairs, 2003, p.28, p.30, p.73).

Another difficulty is the erratic enforcement of the blend mandate as there is no policy to direct this activity. One respondent captured the absence of a biofuels policy and the effect on the blend mandate this way:

> *Not seen one. Challenge is we don't have enough ethanol. So we don't blend everyday – sometimes it's not available. Then depots are advised to sell 100% petrol. Until we can blend the 20% consistently [only] then can we push for more ethanol volume uptake.*

The seasonality of ethanol production due to the sugarcane crop (the source of molasses the ethanol feedstock) further compounds the management of the blend mandate. Awareness, of the threshold volumes of ethanol for consistent blending, needs to be fostered by a policy coordinating fossils and ethanol as well as other biofuels. Addressing the need of a policy to coordinate fossils and biofuels one respondent said:

> *"No…you hardly hear about a biofuels policy or a policy to coordinate biofuels and fossils"*

The respondents affirmed that no biofuels policy exists in Malawi at the moment and emphasized the need for one.

A further question in interrogating the awareness of a biofuels policy was "whether or not Malawi is doing enough to promote ethanol as a bio-fuel and if not what more could be done to promote use of ethanol?" Thirty three out of the thirty three respondents which is 100% were emphatic that not enough is being done to promote ethanol in Malawi.

In response to the question "what should be done?" respondents' proposed a number of options which government can undertake. For example, one respondent proposed that Government should share the burden of researching into biofuels with the private sector because the costs of research and development are prohibitive for the private sector alone. This view was put this way by one respondent:

> *"government must work backwards to add value after the sugar is produced and convert effluent into useful product like fertilizers …Government can do this through its research arms. Technology is available for recycling effluent from molasses conversion. Research cost into effluent conversion is too much for private investors".*

He suggested that since Government is better placed to access grants from global climate change grant funds it should lead in research. The NEPAD Climate Change Fund is an example of a fund accessible by government but not the private sector (NEPAD, 2014). Specific mention is made of effluent treatment from ethanol processing as an area for research given extant technologies.

Mitchell (2010) urges the use of reclamation technologies citing Brazil as an example. While carbon capture technologies are also recommended (IEA, 2013).

Another respondent proposed increasing the blending mandate gradually until it reaches the optimal levels. The respondent said:

> *There was the introduction of mandatory blending in 2009. And the revision of the blending ratio in 2011 [from 10% back to 20%]. These are some of the ways of promoting ethanol production*

The backdrop to this is the change in 2010 from a blend mandate for ethanol with petrol of 10% to 20% (Extra Ordinary Gazette, 31st December, 2010). A further suggestion was that the taxes on ethanol be eliminated given that the reduction from 30% to 10% was already approved.

> *I wouldn't say it's [Government] doing 100% but its moving towards that. I'm aware that they [Government] reduced taxes on ethanol products from 30% to 10%.*

.

The two measures: blend mandate increase and tax reduction on ethanol are recognized as pathways for increasing ethanol production volumes and use. Tax reduction was a recurring theme in this research.

Government is urged to take initiatives to promote ethanol such as importing vehicles that run on ethanol. This suggestion implies that government should move to declare ethanol a standalone fuel. Kambatata (2012) confirms that government has approved the importation of flexi vehicles (vehicles that run on both ethanol and petrol), but ethanol is still not yet declared a standalone fuel. Flexi vehicle importation represents another pathway to increase ethanol use and therefore an incentive to increase ethanol production volumes.

Yet another respondent proposed a 30% price differential between ethanol and petrol as a way of increasing ethanol use. Levies should be removed from ethanol. Price modelling tools were put forward as a means to set the price of ethanol. He then called "for a change of mindset and the need for ethanol to be driven from the brand perspective in arriving at relative price of ethanol to petrol. He pointed out that raising awareness about the importance of ethanol should be taken as an effort to raise awareness about a particular brand.

"You need to drive awareness from both public relations, brand awareness, and opinion leaders".

It may be useful to sample some vehicles and use testimonials as a means for raising awareness about the importance of ethanol.

The finding here is that no one is aware of a policy to coordinate ethanol use and fossils.

4.2.2 Biofuels Strategy

In this section the finding pertaining to biofuels strategy is discussed. The researcher asked the thirty three respondents from the thirteen corporate energy companies and central governement departments if "Malawi has a biofuels strategy". Again thirty three out of the thirty three respondents representing 100 % confirmed that there was no biofuels strategy. The finding is that there is no instrument in the form of a strategy for coordinating biofuels and fossil fuels. One comprehensive response put it this way:

"Interestingly in the strategic reserves there's no talk for ethanol because no one has it in their radar today. They don't even have a tank for paraffin because they think it is too small". Very interesting as a country we are talking of exports as to how we can be self-sustaining. I think fuel is a big area which is not being given the attention it deserves. If we put all eyes on fuel we can drive a lot of things – how can we do localization because all industry is fuel based?"

In this response is captured the inconsistency of uncoordinated policies and strategies. There is a drive for Malawi to become an exporting country while paradoxically there is a failure to deal with the single largest import, fossil fuel. The mandatory ethanol blending programme is fraught with inconsistent blending due to the seasonality of ethanol production (Department of Energy Affairs, 2003) but no policy guideline or strategy exists.

The omission of ethanol from the strategic fuel reserves tank plan is another gap that a biofuels policy would help close. As noted in Chapter 2 (section 2.7.4), from the outset the government fuel storage company NOCMA did not have ethanol storage in its plans inspite of the existing practice of blending petrol with ethanol (Chapter 2, section 2.7.4) .

Another respondent in commenting further pointed out the many possible "spinoffs" from wider ethanol use. He cited the following:

a) Compressed natural gas (CNG) which is compressed methane, a gas that is a product of ethanol production waste (vinasse). CNG can be used to run diesel engines such as farm tractors. According to Johnson and Silveira (2014), a biogas plant meant to capture methane funded by the Dutch government was a failure in the 1990s. However this is being revisited (Khatiwada and Silveira, 2011).

b) Carbon dioxide (CO_2) is a gas that is emitted into the air at the fermentation stage of ethanol production. It is possible to capture this gas and make dry ice normally used in the soft drinks (beverage) industry. Malawi has the opportunity to save on the import bill for CO_2 (Chanje, 1999). More importantly climate change issues get addressed directly by reducing the emission of CO_2. Carbon capture and storage (CCS) technologies now exist (IEA, 2013).

c) Vinasse is the liquid effluent that comes out of ethanol production and is mostly water (85%). This can be sprayed back into sugarcane fields as fertiliser (liquid fertiliser) (Gonsalves, 2006). According to ETHCO (2010), development of the fertiliser programme has helped with the disposal problem while also providing a value-added product to nearby small farmers.

d) Livestock feed from phosphate and urea. Phosphates and urea are used in ethanol production and then washed out at the end of the process. These chemicals could be reclaimed and used in the manufacture of livestock feed. Johnson and Silveira (2014), agree that co-products such as livestock feeds can add value even if they are not fully commercialised.

e) ENA saving import bill. Malawi imports extra neutral alcohol (ENA) for the beer brewing industry and therefore uses foreign exchange which would be saved if more ethanol was produced locally. Other non-energy co-products such as ENA can offer additional economic incentives to producers (Johnson and Silveira, 2014).

These spinoffs show that ethanol can contribute a lot to the economy of Malawi with proper plans and application. The forex savings and economic contributions are discussed in Chapter 4 (sections 4.5.1)

One respondent asked a rhetorical question, "what do we want to achieve in 10 years going forward?" emphasizing the lack of strategy as he saw it. He pointed out that “policy makers do not consult enough with industry and users”. To make ethanol visible as a standalone fuel he proposed that industry begin by setting up two filling stations each in Blantyre, Lilongwe, Mzuzu”. The ultimate consumers’ attention would be attracted resulting in more ethanol uptake.

In summary government is seen as not doing enough to promote the production and use of ethanol. To reverse this situation a number of proposals were put forward by the respondents as follows:

a) Government should develop a policy to coordinate ethanol and fossil fuels.
b) Government should declare ethanol a standalone fuel.
c) Tax reduction and removal of levies by government.
d) Government should lead industry in research and development activities by accessing global funds.
e) Blend mandate should increase gradually.
f) Government should import flexi fuel vehicles.
g) Industry should lead in making ethanol visible to end users by setting up pilot ethanol filling stations in major cities.

4.2.3 Analysis

The respondents confirmed that there was no biofuels policy or strategy in existence. The mandatory ethanol blending programme is fraught with inconsistent blending due to the seasonality of ethanol production (Department of Energy Affairs, 2003) but no policy guideline or strategy exists. A call was made by the respondents for government to put in place a biofuel policy. Brazil, America, the EU, China and India have biofuel policies in place (Chapter 2, sections 2.18.1 to 2.18.5). The EU directive has a number of articles (86,74) directed at the biofuel awareness aspect. An example of the positive influence of an effective biofuels policy is offered by Langevin (2010) in the case of Brazil , where he says legislation in 1975, targeting the growth of sugarcane ethanol production, led to the establishment of the ProAlcool program which provided tax incentives, credits, and infrastructure to sugarcane and ethanol producers. This led to domestic ethanol production quadrupling between 1975 and 1985 (Chapter 2, section 2.14.1)

One proposal to address the visibility of ethanol was that the ethanol industry should install pure ethanol pumps in the major centres of Blantyre, Lilongwe and

Mzuzu. In the Brazil case this aspect was specifically legislated and the ethanol industry had to comply. Further the availability of FFVs and EDVs in Brazil dovetailed neatly with the legislation. The respondents suggested that government should import FFVs as an initiative to make ethanol more visible. The Malawi EDV programme has stalled according to Chinamulungu (2016) once again highlighting the lack of clear biofuel policy and strategy (Chapter 2, section 2.7). In China on the other hand government set up all ethanol pilot plants (Chapter 2, section 2.18.3).

Another respondent proposed a gradual increase in the blend mandate. This echoes the Indian biofuel policy where blending was limited to five percent (5%) in 2009 with a target of twenty percent (20%) by 2017 to allow for the growth of ethanol production volumes as well as the use of ethanol (Chapter 2, section 2.18.4).

Embedded in the responses to the awareness question were responses as to whether government was doing enough to promote ethanol and what government should be doing. A consensus was that levies and taxes on ethanol must be removed. The Indian biofuels policy as a rural development strategy does not tax proceeds from the sugarcane industry. Consequently molasses a sugar processing byproduct and a raw material for ethanol production is tax exempt (Chapter 2, section 2.18.4).

In this section the finding about awareness of the policy and strategy of biofuels was discussed. The research has found out that there is no awareness of either the policy or strategy for biofuels or ethanol. In other words neither the policy nor the strategy exists.

4.3 Objective b): Find pathways of increasing ethanol production

Pathways to increase ethanol production are discussed in this section. Pathways are options available for increasing the production of ethanol in a bid to make it significant in the liquid fuels portfolio (Shinoj *et al*., 2011).

In the search for pathways to increase ethanol involvement in the liquid fuels portfolio the thirty three respondents from the thirteen corporate energy organisations and central government departments were asked to respond to the lead question: “How do you think adequate fuel supplies can be assured in

Malawi in the long term?" Respondents' views are presented in the following paragraphs. The literature review reveals a number of pathways to increase the production volumes and use of ethanol. This section will discuss the findings regarding the pathways for increasing the production volumes such as, feed stock sufficiency, increasing sugarcane yields, increasing land under sugarcane and framing of a biofuels policy. The subsequent section (4.4) will discuss the pathways for increasing ethanol use. Energy strategists' (respondents) views in relation to these pathways for increasing ethanol production are presented and discussed in the following sections.

4.3.1 Feed stock

Increasing and diversifying feed stock is cited as a possible pathway of increasing ethanol production (Mitchell, 2010). Chaudhari (2008) in an analysis of the best feedstock for ethanol production in Africa suggests sweet sorghum, sugar beet, and cassava besides sugar cane. Against this background the thirty three respondents from the corporate energy organisations and central government departments were asked if they knew of any viable energy crops in Malawi. All the thirty three respondents representing 100% responded affirmatively that they know some viable energy crops. Sample responses are presented and discussed in the following paragraphs.

One respondent from the biofuels sector said :

> *"I think right now sugar is the most attractive because it's already broken down into liquid form molasses. But there is now technology that is able to convert whatever cellulose you have into ethanol. The problem is that in countries like Malawi we still look at maize, potatoes, cassava as food crops. They cannot be converted for fuel purposes. But yes technology to breakdown cellulose to monosaccharides and disaccharides is now available and can just be put into the investment. …….Our friends in the US use maize to produce ethanol that cannot be even thought of here because our diet is starch based………... Food staple starches maize etc. can't be used for fuel. Sugar to ethanol [fuel] that can raise the food fuel debate."*

According to Chunga (2015), quoting President Peter Mutharika, says "Malawi is facing one of its worst hunger situations following a twenty seven point seven percent (27.7%) drop in the production of maize". This emphasizes the sensitivity of the use of maize for anything other than food in the Malawi context as pointed out by this respondent.

Another respondent said:

> "*Yes. Those include sugarcane which is used through molasses. There's soya beans and other products such as maize. But it's difficult for maize it's used in the USA but it's more a staple food in Malawi. So that's why we need policy changes. Because the food security policy, although it's not yet documented, has directives on usage of certain crops such as soya beans. But there is not much direction on sugarcane. But I know it can usually come in…once [the ethanol] industry is pushing for maximum production then that will drive policy changes"*

The respondent recognizes that sugar-cane is the best feedstock for ethanol production. Balat (2008), confirms that sixty percent (60%) of global bioethanol production is from sugarcane. Food security issues in Malawi exclude maize from being used for ethanol fuel production as stated by the respondent. Meki (2015), reports that seventeen percent (17%) of the population (2.8 million people) face hunger in 2015 and the government needs to source 124,183 metric tons of maize to deal with this emergency. These figures serve to make the point that maize in Malawi cannot be a fuel energy crop.

One respondent among others cited jatropha as an energy crop. He put it this way:

> *"…..maize and jatropha [are potential crops] for ethanol production"., He then said he was not sure about rice. . "No, wouldn't support maize is a food crop, unless we start growing maize on a commercial basis, which we can do. The GBI is one such way of handling that".*

The respondent gave a condition that we could use maize for the production of ethanol only if we start growing maize on a commercial basis, implying that Malawi does not grow enough. According to Khunga (2015), the food situation is dire following flooding and government is importing maize from Zambia, because the strategic grain reserve only has thirty six thousand one hundred and six (36,106) tons against a requirement of over one hundred and twenty four thousand (124,000) tons. Jeffrey Sachs quoted by Tafirenyika (2013), said this of the late Bingu wa Mutharika, "until his final two years, Mutharika had actually engineered an agriculture-led boom in Malawi, one that pointed a way for Africa to overcome its chronic hunger, food insecurity, and periodic extreme famines". This confirms that Malawi does not grow enough maize for food. The primary use of maize according to this respondent is food and cannot be used for fuel ethanol production. Heisey and Smale (1995) support this view.

The major finding from all respondents is that maize in Malawi cannot be used for ethanol fuel production because it is a staple food in contrast to the American scenario (Demirbas and Balat, 2006). Overwhelmingly sugarcane was seen as the feedstock of choice for ethanol production for Malawi agreeing with the global position of sugarcane as a leading feedstock for fuel ethanol (Balat, 2008). The respondents viewed sugarcane this way because ethanol is produced from molasses a waste product of sugar production. Other feedstocks such as sweet sorghum were acknowledged as possibilities yet to be developed.

4.3.2 Increase sugarcane yields

Shinoj et al. (2011) cites increasing sugarcane yields per hectare as a pathway for increasing ethanol production, which agrees with article 89 of the Directive 2009/28/EC. Interestingly none of the interviewees mentioned this aspect in face to face qualitative interviews showing some lack of knowledge regarding this as a possible pathway. A subsequent direct question was asked as to whether or not the respondents thought increasing sugarcane yields was a possible pathway for increasing the production volumes of ethanol.

Thirty out of the thirty three respondents representing 91% were not aware of the fact that increasing sugarcane yields is a pathway for increasing the production volumes of ethanol. One respondent who was aware said:

> *"There has been an initiative through the National Export Strategy where Government aims at increasing sugarcane production by 50,000MT and the plan is that some sugarcane should be used for ethanol and some for sugar production…".*

The respondents only concurred with the notion of diversifying from sugarcane to other crops such as sorghum. Typical sugarcane yields in Malawi are 100 tons per hectare (TCH) compared to Swaziland who have 103.8TCH (SADC

Sugar Digest, 2014). However the global average TCH is 70.2 and suggests a need for more efforts in developing high yielding sugarcane globally given that 150TCH is achievable (Goes et al., 2011; Pham, 2014). A study by Woods (2000) shows that sugarcane yields 936 litres of ethanol per hectare while sweet sorghum (Keller) yields 561 litres of ethanol per hectare (Chapter 2, section 2.14.3). As more feedstock becomes available, the ethanol production costs will decrease and contribute to economic growth (Mitchell 2010). The lack of adequate feedstock for the ethanol industry continues to be a major challenge.

The finding is that sugarcane yield improvement is a legitimate pathway for increasing ethanol production volumes as well as using other energy crops such as sorghum (Chapter 2, section 2.18.4).

4.3.3 Increase land under sugarcane

Literature shows that more land under sugarcane directly correlates with increased ethanol production as in the case of Brazil (Goes *et al*., 2011; Pham, 2014). This is a recognized pathway for increasing ethanol production volumes.

In response to a question about land for sugarcane the respondents considered increasing land under sugarcane as a pathway to increasing production volumes of ethanol. Thirty three out of thirty three respondents, representing 100%, saw more land under sugar cane as a pathway to increasing the volume of ethanol production in Malawi.

One respondent believes that former tobacco farms can be used to grow sugar cane and thus increase ethanol volumes produced. He was recorded saying:

> *“We can go into tobacco growing areas and grow more sugarcane for ethanol. So not necessary to compete with food. We know that tobacco is going away soon”.*

The respondent was alluding to the anti-smoking lobby gaining strength in Malawi (Jassi, 2015). Due to the traditional dependence on tobacco farming in Malawi for forex generation the researcher asked a probing question to establish the interchangeability of tobacco and sugarcane. The response from one respondent, an agriculturalist, confirmed the feasibility as follows:

“They [sugarcane and tobacco] share climate. Cane requires more water. So sugarcane can replace tobacco especially in warmer areas”.

Toleza farm in Balaka Malawi is a jatropha farm which was a tobacco farm before (Dyer et al., 2012). This supports the view that tobacco farms can migrate into energy crop production.

One respondent in support of more land under sugarcane said:

“To increase ethanol production you need to look at the source of which sugarcane is the bulk. For example small holder farmers – Government must give them a subsidy of some sort”

The implication is that sugarcane is the main ethanol production feedstock and should be subsidized by government targeting small holder sugarcane farmers as has been done for maize farming. The subject of subsidies for small holder (or out grower) farmers was crosscutting in this research. As noted before Malawi produced a surplus in the years 2009 to 2010 due to subsidies on maize inputs (Tafirenyika, 2013; section 4.3.1). Despite this recorded success reservations on the subsidy program in Malawi are sometimes expressed by the development partners (donors) (Chibwana *et al.,* 2012; Gondwe, 2014).

Another respondent concurred and said:

“Government is looking at encouraging production by smallholder farmers, especially those directly involved in sugarcane production”.

In Brazil, according to Goes et al (2011), area under sugarcane has grown by 35% from 1940 to 2010 while sugarcane yields per hectare have grown by 43% from 40 tons per hectare (TCH) to 79TCH in the same period. Landell et al (2010) quoted by Goes et al (2011, p.3) claim that yields of 150TCH are achievable. The global average TCH is quoted at 70.2 by Pham (2014). This suggests that land requirements for sugarcane cultivation can be greatly reduced via the use of new high yielding sugarcane varieties (Chapter 2, section 2.18.1)

The finding is that more land for growing sugarcane is a pathway for increasing ethanol production volumes in Malawi. Subsidies for sugarcane small holder farmers should be offered by government. Tobacco farms that are closing down provide an opportunity for growing more sugarcane.

4.3.4 Analysis

The respondents identified two pathways for increasing ethanol production as increasing feedstock options, and increasing land under sugarcane. The third pathway was noted in the literature review as increasing sugar cane yields. This was not mentioned by respondents.

Feedstock options mentioned by the respondents were sugarcane, maize, soya beans, potato, cassava and sweet sorghum. The respondents were careful to point out that using sugar as feedstock for ethanol production "*can raise the food fuel debate".* This resonates with the Indian biofuels policy which specifically allows the use of molasses as feedstock but not sugar (Chapter 2, section 2.18.4). Sugar was recognized as being the best feedstock by the respondents because it is already broken down into liquid form. Malawi like Brazil and India uses sugar molasses as feedstock for ethanol production. However the Brazil model goes a step further and actually uses sugar as feedstock (Chapter 2, section 2.18.1). Literature shows that sugar is the prime feedstock because it has twice the ethanol yield per hectare than maize, uses less nonrenewable fuel to produce ethanol, and has more byproducts such as electricity (Xavier, 2007). Unlike other starch crops such as maize, sweet sorghum and cassava, according to Fumo (2009) sugar does not need any conversion from carbohydrate to sugar and is therefore the cheapest feedstock to process. Sugarcane beats sweet sorghum as an ethanol production feedstock because it has a seventy percent (70%) higher ethanol yield (Woods, 2000).

Maize was excluded by the respondents because it is a food crop in Malawi. Tafirenyika (2013) underscored this by pointing out that in the maize bumper harvests of 2011 and 2012 Malawi had apparently vanquished hunger.

Increasing sugarcane yields is recognized in literature as a pathway to increasing ethanol production (Chapter 2, section 2.14.3). Respondents did not mention this pathway. Literature recognizes this as a pathway for increasing ethanol production. Xavier (2007), indicates that there are over five hundred (500) commercial sugarcane varieties in Brazil. In the Indian case a recommendation is made that ethanol production can be increased by increasing sugarcane juice yields thus increasing the molasses available for ethanol production (Chapter 2, section 2.14.3). Another pathway for increasing ethanol production is the improvement of ethanol extraction methods of ethanol from molasses (Chapter 2, section 2.14.3). A third pathway found in literature is to increase sugarcane yields per hectare. Given that molasses is the only ethanol production feedstock in use in Malawi these pathways seem relevant. Yet another possible pathway found in literature is using agricultural wastes to produce ethanol (Khan *et.al*., 2012). However it has been noted that this feedstock represents second generation biofuels (Chapter 2, section 2.13). Spencer (2011) says second generation biofuels are being developed in Brazil, China and Thailand (Chapter 2, section 2.12). These pathways were not mentioned by the respondents.

Increasing land under sugarcane was mentioned by respondents as a pathway for increasing ethanol production. Use of former tobacco farms was proposed as a viable means of achieving this. This agreed with the literature reviewed (Chapter 2, section 2.14.6).

4.4 Objective c): Find pathways for increasing ethanol use

In the previous section 4.3 the findings on the pathways for increasing ethanol production volumes were discussed resulting from the responses to the lead question "How do you think adequate fuel supplies can be assured in Malawi in the long term?" (Section 4.3) This section deals with how to increase the usage of ethanol. The literature review revealed government incentives and ethanol pricing as pathways for increasing ethanol use. In the following the responses of the energy strategists are discussed and the findings presented.

4.4.1 Government incentives

According to Mitchell (2010), government incentives for ethanol production and use are a way of increasing the volume and use of ethanol. Demirbas (2008) concurs and says incentives to encourage ethanol production must be provided initially by the government. Over the long term, fuel companies should experience the benefits of using the ethanol blend and thus government intervention would give way to the market forces. Against this background, a question as to whether or not incentives should be offered to potential ethanol producers by government was posed to the thirty three respondents from corporate energy organisations and central government departments. Thirty three out of thirty three, representing 100%, respondents agreed that incentives must indeed be offered. However as the following sample of responses shows there is a wide range of suggested incentives to be offered.

One respondent said the following:

> *"I believe substantial duty incentives should be given to import ethanol conversion kits as well as ethanol burning vehicles either in 100% form or in the range 10 to 90. ….. Ethanol Production equipment must have substantial duty incentives – if ethanol is for fuel. Price incentives –ethanol should be cheaper than petrol to attract users. ….Copy Brazil subsidy for fuel ethanol".*

This respondent raises three areas that must be incentivized. First, Government must provide duty incentives to support the re-introduction of ethanol propelled vehicles and conversion kits for older cars in Malawi. This would see an increase in the demand for ethanol and thence the use of ethanol. Secondly ethanol production equipment should be imported nearly duty free. This would attract investment in ethanol production and lead to higher volumes of ethanol. Thirdly, the price of ethanol should be substantially lower than that of petrol. This would be a step in decoupling the price of ethanol from the price of petrol leading to ethanol being offered to end users as a standalone fuel (Chapter 2, Section 2.15).

One respondent argued that incentives needed to be granted later rather than now. The reason given was that

> *"the country is currently producing less than what the market probably wants".*

He suggested that the ethanol companies should first ramp up their production before government offers incentives for ethanol use. The private sector initiative to import fuel flexi vehicles, as reported by this respondent, was a move to be "encouraged" or incentivized. He described it as follows:

> *"I've heard of some 60 vehicles by PCL to run on 100% ethanol and they can switch to petrol at any time, I understand. That too can be encouraged".*

The respondent is pointing out the importance of Government providing incentives promoting the introduction of flexi vehicles. Government has approved for its own fleet the importation of flexi vehicles (Chinamulungu, 2015).

A more pointed response put it this way:

> *“ incentives have to be there such as reduction in taxes like giving waivers on levies on fuel products such as rural electrification. Define in the Act what can be waived by the minister. Road levy, those can be pegged at a reduced rate as compared to petrol. Also incentives in terms of infrastructure for the production facilities those can be considered.”*

A revision or amendment of the Energy Act is proposed to empower the minister to waive levies on fuel products. Again the respondent here implies that ethanol should be a standalone fuel. Next a decoupling of the ethanol price from that of petrol is called for. Finally, reduced or duty free status for imported ethanol production equipment is recommended.

Some said that small holder sugarcane farmers must be incentivised by government through agricultural subsidies. According to Gondwe (2014) subsidies in Malawi such as the farm input subsidy programme (FISP) are sometimes a source of controversy between government and aid partners (donors). Political expediency in Malawi make agricultural subsidies a permanent feature (Chibwana and Fisher, 2011). Literature demonstrates that the successful biofuel regimes were subsidized at some stage and some continue to be (Chapter 2, sections 2.15.1 to 2.15.6). The pricing of ethanol and removal of levies built into it were a recurring theme among respondents when clarifying answers during the semi-structured interviews. The typical price build up for petroleum products by MERA has six levies also applied to ethanol making up over 74% of the blended petrol duty free price (MERA, 2011; Figure 4.4.2).

The general finding is that, it is a good thing for Government to subsidize on any attempt to increase the use and production of ethanol. Specific activities for government and industry indicated are subsidizing of sugarcane small holder farmers, importation of fuel flexi vehicles and ethanol production equipment, removal or reduction of levies on ethanol and declaring ethanol a standalone fuel.

4.4.2 Ethanol price

The researcher also probed the role of ethanol pricing as a potential pathway for increasing the use of ethanol. Shinoj et al. (2011) suggests increasing the price of ethanol to spur production volumes as a pathway for increasing ethanol production in the Indian context. In this context a question was asked to the thirty three respondents from the corporate energy organisations and central government departments as to “What policy changes should be instituted to promote ethanol”. The responses targeted ethanol price reduction as a required policy change to increase ethanol use. Thirty two out of the thirty three representing 97% argued for a lower ethanol price.

One respondent suggested that the price differential between ethanol and petrol should be at least thirty percent (30%) as follows:

> *“again there should be motivation for you to drive .to pay at a low price that can pull you up, so if you start the price at 10% it will not change somebody’s mindset. But if you get to 30% and above then you see people change.”*

Implicit in this response is that ethanol should be a standalone fuel. A categorical response said *“that ethanol is not treated as a stand-alone fuel”* meaning that government policies must be synchronized in this respect for consumers to benefit from ethanol use. Another response urged that the price be delinked from that of petrol and expressed it this way:

> *“The price of ethanol should be unhooked from the price of imported petrol”.*

In support of this view another respondent said:

> *“Price incentives –ethanol should be cheaper than petrol to attract users… Copy Brazil subsidy for fuel ethanol”.*

The ethanol price must be substantially lower to entice consumers. This was seen as directly promoting ethanol use. Ethanol companies were called on to lower the price of ethanol and disengage from using the maximum allowable price which is pegged to the petrol price (Figure 4.4.2). This it was argued would encourage ethanol use.

The levy structure embedded in fuel pricing as shown in Figure 4.4.2 was singled out by other respondents as an obstacle to the growth of the ethanol industry hence ethanol volumes and use. The response put it this way:

> *“but perhaps the pricing, because all the costs, levies are not encouraging ethanol production. These levies are not growing the industry”.*

Tax reductions were seen as a step in making the ethanol attractive and a pathway for increasing the use of ethanol. This agrees with the practice in India where there are “no taxes” on sugar cane proceeds (Chipukunya and Kacelenga, 2011).

Consistent with other literature reviewed, the pricing of ethanol versus petrol was seen as a tool to promote the wide use of fuel ethanol (Er, 2011). The price of ethanol in Brazil was capped at 65% of the petrol price so as to make it more attractive to consumers (Chapter 2, section 2.18.1). The price of ethanol in Malawi is currently linked to the import price of petrol and carries levies similar to those on petrol (Figure 4.4.2).

The scenario pictured by Shinoj et al., (2011) is one where ethanol has been declared a standalone fuel with consumers convinced of the benefits. In contrast Malawi has not yet declared ethanol a standalone fuel. The current legislation is for blending with petrol (Extra Ordinary Gazette, 31st December, 2010). Malawi ethanol was seen by the respondents as too expensive and therefore a barrier to wider use as a standalone fuel.

The finding was that the ethanol price changes constitute a pathway to increased ethanol use. Therefore the ethanol price should be delinked from the petrol price with a differential in excess of thirty percent (30%) and that ethanol should be declared a standalone fuel. The levy structure needs to be revised in favour of ethanol. The ethanol industry could take the lead and lower the price since the regulator (MERA) normally specifies the upper limit only.

Figure 4.4.2 Fuel Price Build up

PETROLEUM PRODUCTS PRICE BUILD UP IN MALAWI EFFECTIVE 28TH JANUARY 2011 (Given in tambala per litre)			
	Petrol	Diesel	Paraffin
FOB	9,766.21	10,516.91	7,134.04
RAILAGE	71.97	203.25	-
ROAD FREIGHT	2,027.15	1,222.14	1,035.90
INS/HANDLING	95.16	90.00	58.69
LOSSES	59.21	70.00	49.50
IBLC (BT/LL)	**12,019.70**	**12,102.30**	**8,278.13**
ENERGY REGULATORY LEVY	100.00	100.00	100.00
ROAD LEVY	2,870.00	2,370.00	-
MBS CESS	15.82	16.67	16.91
SAFETY NET LEVY	1,982.00	1,982.00	400.00
RURAL ELECTRIFICATION LEVY	1,305.00	1,170.00	697.50
STORAGE LEVY	500.00	500.00	500.00
PRICE STABILIZATION FUND	3,203.00	1,110.22	1,563.61
DUTY FREE PRICE	**21,995.52**	**19,351.19**	**11,556.15**
DUTY	791.23	833.56	422.71
EXCISE DUTY	2,524.02	2,750.74	1,331.53
DUTY PAID PRICE	**25,310.77**	**22,935.49**	**13,310.39**
DISTRIBUTION MARGIN	**233.00**	**233.00**	**233.00**
GROSS MARGIN	1,803.19	1,350.00	1,075.99
WHOLESALE PRICE	**27,346.96**	**24,518.49**	**14,619.38**
RETAIL MARGIN	1,653.04	1,481.51	880.62
PUMP PRICE	**29,000.00**	**26,000.00**	**15,500.00**
Kwacha per litre	**290.00**	**260.00**	**155.00**
Percentage Change	**13.19**	**12.46**	**6.60**

All Correspondence to be Addressed to the Chief Executive Officer

Source: MERA, 2011

4.4.3 Analysis

The respondents advocated for strong government intervention to encourage the use of ethanol (Chapter 2, section 2.15). China's biofuel strategy demonstrates strong and continuous government intervention at every stage of ethanol development (O'Kray and Wu, 2011), On the other hand the Brazilian government interventions were removed with time so that currently only the blend mandate remains (Mitchell, 2010). A variety of ways were put forward. A subsidy for small holder sugarcane farmers was proposed as one way of encouraging ethanol production hence use. The Indian biofuel strategy prohibits large estates from growing sugarcane and supports small sugarcane farmers as a development strategy (Chapter 2, section 2.16.4). This in turn increases the raw material available for ethanol production and hence use. Brazil on the other hand encourages the large sugarcane farms by giving them incentives to produce sugar specifically for ethanol (Xavier, 2007).

Another proposal was that government should import FFVs. This mirrored the Brazilian strategy of manufacturing FFVs with the intention of increasing the use of ethanol for transportation (Chapter 2, section 2.15.1). It must be noted that this aspect of the Brazilian strategy has not been replicated elsewhere (Chapter 2, section 2.15.1). Malawi in the past had EDVs piloted and the respondents urged that the programme be resumed with conversion kits being offered to increase the use of ethanol. Tax breaks were offered to Brazilian EDV and FFV car owners to incentivize the use of ethanol (Chapter 2, section 2.15.1.). Respondents noted that the private sector was planning to import FFVs and proposed that there should be no duty paid for these vehicles. This they argued would encourage the demand for ethanol and increase its use. Respondents also suggested that ethanol manufacturing equipment should be exempted from import duties as a way of increasing ethanol volumes in Malawi.

Removal of levies from the ethanol price was presented as a pathway for increasing ethanol use. A delinking of the ethanol price from the petrol price was proposed. The Indian biofuels policy has price controls embedded for the benefit of sugarcane farmers and not petrol users (Shinoj et.al., 2011). In China, price regulation in the biofuel policy is vigorous and is aimed at keeping the price of petrol higher than ethanol for the growth of ethanol use and production. Brazil on the other hand has a price cap of sixty five percent (65%) for ethanol (Mitchell, 2010). This encourages the use of FFVs and EDVs and hence increases the use of ethanol. The respondents also urged that ethanol should be declared a standalone fuel a situation that obtains in China and Brazil. The EU and India have blend mandates at five percent (5%) while the Malawi blend mandate is at twenty percent (20%).

Pathways proposed by the respondents for increasing ethanol use were subsidies for smallholder sugarcane farmers, FFV imports, and ethanol manufacturing equipment. Delinking the price of ethanol from petrol and removal of levies was also proposed as an appropriate government action to enhance ethanol use.

4.5 Objective d): Investigate sustainability criteria for ethanol production

Ethanol production must be sustainable for long term benefits to accrue. According to Hecht (2011),"biofuels sustainability research will provide better information to decision makers on the tradeoffs and opportunities of increased biofuel production". Literature reviewed shows that there is a plethora of biofuels sustainability criteria and approaches available (Chapter 2, section 2.17.1). In this section the sustainability criteria emanating from this research, for ethanol production are discussed.

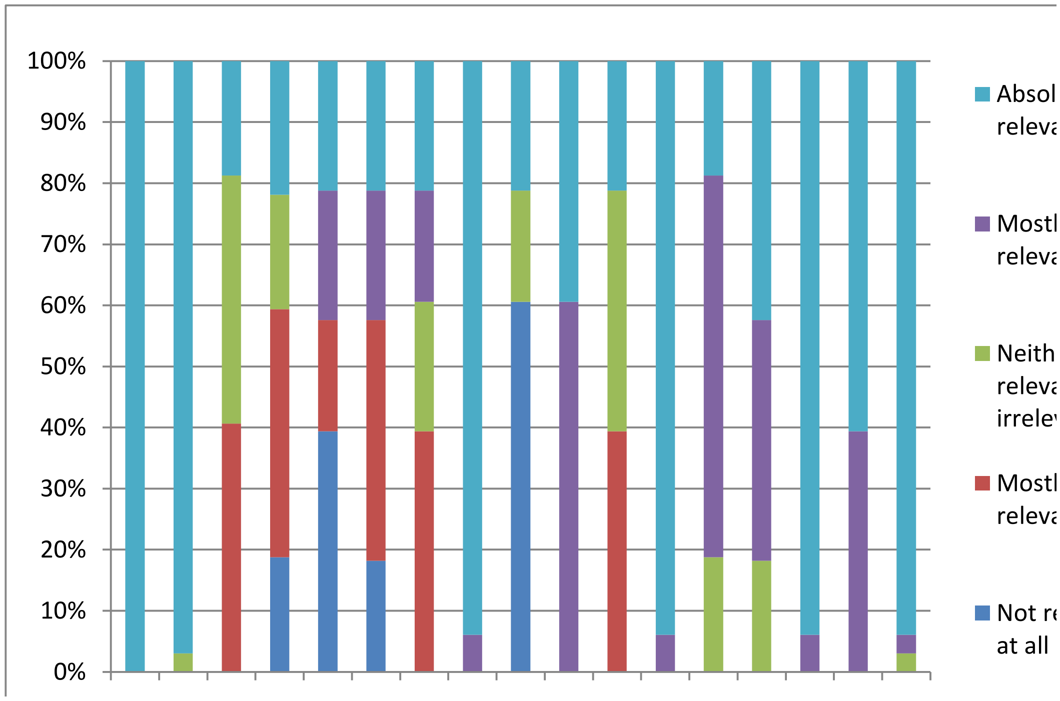
The definition for sustainability according to Purchas and Hutchinson (2008, p.5) is "the ability to produce biofuels to contribute to today's fuel needs without compromising the ability of productive land to meet current and future food and fuel needs". According to the Directive 2009/28/EC biofuels are to be used to reduce GHGs by 35% (European Parliament Council, 2009) while in Brazil the 1986 biofuel programme, National Motor Vehicle Emissions Control, also targeted the reduction of GHGs (Chapter 2, section 2.13). This shows that in Brazil and in EU countries biofuels are viewed as sustainable primarily if they effectively address GHGs or climate change issues (Brieskorn, 2011; Jamieson, 2011; Rastogi, 2011). Against this background, the researcher wanted to establish how bio-fuel sustainability is viewed in Malawi.

A quantitative questionnaire was concurrently administered during the face to face interviews aimed at determining the relevant sustainability criteria. The seventeen sustainability criteria investigated and rated were developed by Fumo (2009) and provided a launch pad for this analysis. The criteria are listed in Table 2.17.1 and coded to facilitate analysis and drawing of the frequency graph in Figure 4.5.2

4.5.1 Relevance of biofuel sustainability criteria for Malawi

A self-administered quantitative questionnaire (Appendix II) was administered to the same thirty three respondents from the thirteen corporate energy organisations and central government departments concurrently with the semi-structured interviews. This questionnaire probed issues of biofuel sustainability criteria only as reflected in objective c). The objective was to obtain the perceptions of the target audience regarding ethanol production sustainability. The questionnaire had a Likert type scale for establishing the relevance of each sustainability criterion ranging from 1 to 5 (Appendix II). The ratings were as follows: 1= not relevant at all, 2= mostly not relevant, 3=neither relevant nor relevant, 4=.mostly relevant, 5= absolutely relevant. Figure 4.5.2 shows the results of the frequency ranking of the relevance criteria as viewed by the interviewees in the thirteen targeted organisations. The sustainability criteria viewed as most relevant by the respondents are displayed in Figure 4.5.2. Table 4.5.2 emphasises the relevance ratings as indicated by the respondents together with sample quotations. The first row is for the criteria rated as “Absolutely relevant” while the second row is for the “Mostly relevant criteria and the third row is for the “Neither relevant nor irrelevant” criteria.

Figure 4.5.2 FREQUENCY OF RESPONSES



Source: Author

Henry (1990) quoted by Saunders et al., (2000, p153) says “for populations of less than 50 cases probability sampling should not be done. Data should be collected on the entire population to avoid the influence of a single extreme case being more pronounced". In this research there were thirteen targeted corporate energy organisations and central government departments representing the whole energy sector with thirty three respondents. Of the seventeen (17) criteria investigated six (C1, C2, C8, C12, C15, C17) emerged as the most important (Absolutely relevant). The ***absolutely*** relevant criteria in order were:

C1: Positive contribution to Malawi liquid fuel volume as an import substitute.

C2: Improves air quality (pollution) through emissions reduction

C8: Affects forex availability as an import substitution

C12: Improves energy security

C15: Reduces dependence on imported oil

C17: Impacts on local culture - social welfare

Table 4.5.2 : Relevance Rating: Sustainability Criteria

RELEVANCE RATING	SUSTAINABILTY CRITERIA	SELECTED RESPONDENT REMARKS
Absolutely relevant	**C1** Positive contribution to Malawi liquid fuel volume as an import substitute. **C2** Improves air quality (pollution) through emissions reduction. **C8** Affects forex availability through import substitution. **C12** Improves energy security **C15** Reduces dependence on imported oil (serves as petrol import substitution) **C17** Impact on local culture – social welfare	"All in all this ethanol has a net positive effect on the Malawi economy via the positive effects arising from quantity enhancement through blending and price stabilization" "reduces pollution as compared to petrol" " Malawi has .. unsustainable and narrow foreign exchange "earning" base, .." “To a greater extent. Could do better if volumes were increased” ".. Malawi has and will continue to diversify its fuel sources thereby improving its fuel security status,.... given the country's landlocked nature..." “for economic development; provision of employment”.

Mostly relevant	**C5** Affects soil erosion **C6** Affects price of land **C7** Affects biodiversity (forests) **C14** Affects national import costs	"may increase soil erosion by opening of new land" " the question of land meant for food crops being appropriated for ethanol feedstock production and/or instigating and fueling an escalation in land prices, in the Malawi context and in many other countries' contexts- where sugarcane is grown for ethanol production-for that matter, does not arise."
Neither relevant nor irrelevant	**C3** Land use: Competes with food crops **C4** Protects water quality (pollution) **C9** Affects food prices **C11** Reduces use of charcoal **C13** Increases water usage	"Ethanol production cannot necessarily affect food production ... land used for ethanol feedstock is not automatically suitable for maize production" "if use of ethanol for cooking is promoted" "through irrigation"

Source: Author

The six criteria (C1, C2, C8, C12, C15, and C17) rated as most relevant in Table 4.5.2 are presented and reviewed in the light of the interview responses and literature in the following sections 4.4.2.1 to 4.4.2.6. The topical issue of LUC (or ILUC) debate is also discussed in section 4.2.1.7 although the respondents did not see it as important and rated it neither relevant nor irrelevant. Some of the respondents' views are highlighted.

4.5.1.1 Positive economic contribution: import substitution

All the thirty three (100%) respondents from the thirteen energy organisations agreed that sustainable ethanol use would make a positive economic contribution (C1) to Malawi (Table 4.5.2). This was the highest rated sustainability criterion of all the seventeen (see Figure 4.5.2). An energy strategist captured the economic impact of blending petrol with ethanol as follows:

> *"It is huge. As a landlocked country that relies on hauling most of its imports and exports by road, the costs of hauling the liquid fuel like diesel, petrol and paraffin impacts heavily on the economy."*

According to Chirwa (2015) landlocked Malawi has continuously searched for means of reducing the cost of doing international trade and related logistics and the costs are reflected in high delivery commodity prices, expensive import prices, and uncompetitive export prices. Ziba (2010) says, the 2005 Malawi Transport Costs Study indicates that Malawi spends 250 million US dollars every year to export its goods as well as to receive goods from other countries. The Shire Zambezi Inland Port Waterway project is a government initiative designed to address the high road haulage import costs (State House Malawi, 2015).

Another respondent expressed a similar view this way:

> *"All in all this ethanol has a net positive effect on the Malawi economy via the positive effects arising from quantity enhancement through blending and price stabilization"*

This captures the dual role of ethanol both as enhancing the liquid fuel portfolio in terms of volume and benefiting the economy through cushioning the price volatility of fossil fuel.

Robinson (2009) describes the first major fossil fuel outage in Malawi and how the economy came to a standstill during this period. Ethanol is a recognized solution to fossil fuel shortages and changing the fuel portfolio away from being fossil dominant (Balat, 2009). Economic development is cited by Buis (2012) as a benefit of ethanol use. MERA (p.4, 2008) mentions that the raison d'etre for ethanol is to “realize economic benefits” as seen from the following extract, the only place ethanol is mentioned in the first four year strategic plan (Chapter 1, section 1.6):

“Expanding the ethanol-petrol blending ratio, currently at 10:90, will further realize economic benefits of locally produced fuel ethanol. This will reduce the burden of foreign currency exerted by the bulk fuel imports. Further, MERA will support GoM's [government of Malawi] Rural Electrification Programme. Supporting the generation and distribution systems of capacities up to 5MW in rural Malawi will enhance and improve rural livelihoods, welfare and also expand income generation opportunities”.

The linkage between rising oil prices and the acknowledgement that biofuels in general and ethanol in particular provide a credible alternative to fossils is well documented (O’Kray and Wu, 2010; Gonsalves, 2006; Balat, 2008; Shinoj et.al., 2011). According to Nji and Cameroon (2006), soaring world crude oil prices are pushing non-oil producing African countries to seek ways of lessening their dependence on oil. Biofuels are categorically stated as the major substitute for fossils (European Parliament Council, 2009).

The finding in this research is that economic contribution (or benefit) is the number one criterion for sustainable ethanol use (see Figure 4.5.2). This position contrasts with the EU reason for biofuel use and the 1986 Brazilian National Motor Vehicle Emissions Control programme raison d’etre, namely addressing GHG climate change issues (Xavier, 2007; European Parliament Council, 2009; Mitchell, 2010). It maybe postulated therefore that activities addressing issues of poverty are prioritized in the Malawi context. MERA (2008, p.4) supports this conclusion by stating that ethanol use “*will enhance and improve rural livelihoods, welfare and also expand income generation opportunities”.*

4.5.1.2 Air quality improvement

A second sustainability criterion was that air quality must improve with the use of ethanol (Table 4.5.2). Thirty two out of thirty three (97%), said that ethanol has a positive net effect on air quality as it reduces pollution. This was neatly stated by one respondent as follows:

> *"Reduces pollution as compared to petrol"*

The respondents agreed that ethanol mitigates the negative climate change issues and helps Malawi meet its international obligations. According to the Environmental Affairs Department (2002, p.6),

“The Republic of Malawi signed the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992 at Rio de Janeiro, Brazil”.

This demonstrates Malawi’s solidarity with the International Community against the global threat of Climate Change. Furthermore, Malawi ratified the UNFCCC on 21st April 1994 and became a Party to the Convention showing the Country’s total commitment to addressing the climate change issues nationally and globally through co-operation. One respondent said that ethanol was

> *“environmentally friendly and that was good for all”*.

The two major reasons for ethanol use are high fossil fuel prices and climate change concerns (Jamieson, 2011). De Oliveria et al., (2005) mentions Sweden as a leading user of ethanol due to climate change concerns, even though most of it has to be imported. One respondent pointed out that ethanol should be used to address the *“Carbon foot print – climate change concerns and environmental issues”*.

An example of action in this regard is the 1986 Brazillian National Motor Vehicle Emissions Control programme targeting GHGs, which according to Mitchell (2010), brought a ninety six percent (96%) reduction of carbon monoxide, hydrocarbons, nitrogen oxide (NOx), and total aldehydes by 2008. Many authors agree that ethanol blended fuels burn cleaner and produce lower emissions and hence less air pollution (Ahmad *et al.*, 2013; Buis, 2011; Low and Isserman, 2009; Balat, 2008; Saka et.al., 2005). In the USA, McGrath (2015), reports that President Obama’s revised “Clean Power Plan” aims to cut greenhouse gas emissions from US power stations by nearly a third within 15 years.

While agreeing that ethanol addresses climate issues, one respondent added that the ethanol production process has other spin off advantages even though it releases carbon dioxide (CO_2) into the atmosphere. He said the captured CO_2

> *“Can be used to save [on the] import bill on CO_2 for beverage industry. Harnessing CO_2 can cut the import bill for the beverage industry”.*

The finding is that ethanol use has a net positive impact on climate issues through the reduction of vehicle emissions, GHGs, and thus reducing air pollution is a sustainability criterion. However, this research through the relevance rating (see Figure 4.5.2; Table 4.5.2) shows that in Malawi the GHG mitigation occupies second place as a criterion for sustainability unlike in the EU, Brazil and the USA where the reduction of GHGs is the primary reason for using biofuels (McGrath, 2015; European Parliament, Council, 2009; Xavier, 2007; Mitchell, 2010). According to the Environmental Affairs Department (2002) quoting the then President Muluzi, said "It is pleasing to note that the UNFCCC recognises that socio-economic development and poverty eradication are overriding priorities of developing countries". This resonates with the finding that GHG issues are placed second in Malawi after poverty.

4.5.1.3 Positive forex effect

According to the relevance rating Table 4.5.2 thirty one out of thirty three (94%) respondents stated that sustainable ethanol use must have a positive net effect on forex (foreign exchange) through import substitution of fossils by ethanol.

One respondent said that:

"Malawi has [an] unsustainable and narrow foreign exchange earnings base, and … that ethanol use is a solution".

Another respondent concurred and put it this way:

> *"Don't see why Malawi has not followed [the] Brazil example to replace imported fuels by ethanol. Any and all uses of ethanol must be encouraged to replace fossils via blending, flexis etc. Pity that Government does not push in this direction. Agriculture [is] major user of imported fossil fuels in Malawi – believe that ethanol can replace fossils completely and save farmers on use of expensive fossils".*

The agriculture sector in Malawi, in 2010 consumed 56,780 metric tons diesel versus diesel imports of 194,000 metric tons, while transport diesel consumption was 129,000 metric tons (United Nations, 2014). Petrol volumes imported = 110,000,000 litres (PIL, 2011)

Diesel volumes imported = 225,000,000 litres

Paraffin volumes imports = 15,000,000 litres

Duty free price of petrol (2013)	= MK 544.83 per litre (MERA, 2013)
Exchange rate: 1 USD	= MK 415.01
Total duty free diesel imports	= MK 119,234,250,000
Total duty free petrol imports	= MK 59,931,300,000
Total duty free paraffin imports	= MK 7,614,747,000
Total duty free fossil bill	= MK 186,780,297,000
Saving if 20% blend petrol used	= MK 11,986,260,000 (MK 12 billion)
Saving % on total fuel import bill	= 6.4%
Forex saving on petrol alone	= USD 28,881,858 (USD 29 million)
Saving if 20% diesel blend	= MK 23,846,850,000 (MK 24 billion)
Saving % on total fuel import bill	= 12.8%
Forex saving on diesel alone	= USD 57,462,000
GDP per capita (2014)	= USD158 (World Bank, 2015)
GNI per capita (2014)	= USD250 (World Bank, 2015)

These figures show that almost a third (30%) of diesel is used in agriculture representing significant potential savings if ethanol is used instead as suggested by the respondent. The calculations in the box demonstrate the forex quantum involved. According to Malikwa (2016) an AfDB food crisis response of USD 17 million will benefit over 700,000 food insecure people in Malawi. The forex saving on petrol alone is USD 29 million equivalent to a benefit for 1.2 million people. This clearly shows that at a minimum full compliance with the current twenty percent (20%) ethanol blend mandate makes a significant difference to the Malawi economy.

Figure 4.5.1.3 Fuel Price Build Up

PETROLEUM PRODUCTS PRICE BUILD UP IN MALAWI			
EFFECTIVE 12TH MARCH 2013			
(Given in tambala per litre)			
	Petrol	Diesel	Paraffin
FOB	41,257.09	41,989.02	43,323.24
ROAD FREIGHT	5,154.53	5,161.11	5,334.60
INS/HANDLING	292.24	291.46	245.42
LOSSES	223.11	173.73	243.65
IBLC (BT/LL)	**46,926.97**	**47,615.32**	**49,146.91**
ENERGY REGULATORY LEVY	300.00	300.00	300.00
ROAD LEVY	1,200.00	1,200.00	-
MBS CESS	93.85	95.23	98.29
RURAL ELECTRIFICATION LEVY	**2,443.72**	**382.65**	
STORAGE LEVY	500.00	500.00	
PRICE STABILIZATION FUND	3,018.82	2,899.77	1,219.78
DUTY FREE PRICE	**54,483.36**	**52,992.97**	**50,764.98**
DUTY	4,692.70	4,761.53	2,457.35
EXCISE DUTY	5,161.97	5,237.69	2,580.21
DUTY PAID PRICE	**64,338.03**	**62,992.19**	**55,802.54**
IMPORT MARGIN	200.00	200.00	200.00
IMPORTERS PRICE	**64,538.03**	**63,192.19**	**56,002.54**
DISTRIBUTION MARGIN	**233.00**	**233.00**	**233.00**
GROSS MARGIN	2,672.37	2,027.64	1,679.56
WHOLESALE PRICE	**67,443.40**	**65,452.83**	**57,915.10**
RETAIL MARGIN	4,046.60	3,927.17	3,474.90
PUMP PRICE	**71,490.00**	**69,380.00**	**61,390.00**
Kwacha per litre	**714.90**	**693.80**	**613.90**
Percentage Change	**1.51**	**1.49**	**3.80**

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Source: MERA (2013)

According to Low and Isserman (2009) ethanol is an attractive political solution for a range of problems from global warming to national energy security to local economic development (Chapter 2, section 2.19). The availability of forex positively impacts economic development. NSO (2011) says ethanol use as a fuel reduces the amount of foreign exchange spent on fuel imports. Nkomo (2009, p.20) explains that "price fluctuations result in a flow of foreign exchange resources to oil producers, which would otherwise be used to stimulate the economy".

The finding is that ethanol use is a solution for forex shortages and is considered a major sustainability criterion by ninety four percent (94%) of the respondents. The finding converged with literature.

4.5.1.4 Energy security improvement

Thirty out of thirty three (91%) respondents from the thirteen energy related organisations stated that energy security is a sustainability criterion for ethanol use. Energy security is enhanced by reducing fossil oil dependence (Nkomo, 2009). The thrust is that the progressive reduction of fossil fuels in the liquid fuel portfolio follows increasing ethanol volumes. One respondent agreed that energy security is positively impacted by ethanol use but said

> *"could do better if volumes were increased".*

Another respondent from had a view underpinned by history on energy security and expressed it this way:

> *"I think we look at fuel supplies in terms of sustainability in the country. Being a land locked country we have a lot of challenges, to begin with and that poses the whole challenge of reliability as we don't have a port we have to import, it is a challenge".*

There is an event in the history of liquid fuels in Malawi noted in the literature review where in 1979 there were fuel queues caused by war in neighbouring Mozambique (Chapter 2, section 2.12). According to Gonsalves (2006, p.13) "Renewable energy, including biofuels, can help diversify energy supply and increase energy security". Energy security is affected by a number of factors such as collusion among oil exporting countries, insufficient diversification and political uncertainty among others (Nkomo, 2010). According to Low and Isserman (2009) ethanol is an attractive solution for a range of problems from global warming to national energy security. Xavier (p.5, 2007) says of the Brazilian national alcohol program, "PROALCOOL was both an energy security program and an agricultural price support program".

One respondent said it is advantageous to use ethanol as a fuel because

> *"you are in control of it yourselves as a country. Its locally produced and its agrobased".*

The finding is that energy security is a sustainability criterion. The respondents' reason was that because Malawi is landlocked, there was a need to have control over fuel supplies and ethanol was seen as the solution consistent with literature.

4.5.1.5 Fossil dependence reduction

The reduction of fossil fuel imports is seen as a desired result following the use of ethanol fuel (Kambatata, 2012). Thirty one out of thirty three (94%) respondents listed this as a criterion for sustainable ethanol use. One respondent presented it this way:

> *"Any and all uses of ethanol must be encouraged to replace fossils via blending, flexis etc."*

Recent government pronouncements indicate the intention to introduce ethanol driven vehicles on its fleet. Chinamulungu (2015) quotes a government official saying:

"..we will among our vehicles put others that will be using ethanol. This will enable government to save money spent on fuel purchases for other essential purposes".

Malawi has suffered from serious fossil fuel shortages over the years for reasons ranging from conflict in neighbouring countries to foreign exchange shortages (Robinson, 2009; Lea and Hanmer 2009; Kambatata, 2012). Ethanol production in Brazil as an alternative fuel in the 1970s was prompted by the need to reduce oil imports following the oil crisis (Balat, 2009). High oil prices caused by instability in many producer countries, global warming (climate change issues) and fears of the approaching "peak oil" are driving renewed interest in biofuels (Balat, 2008). One respondent talking about "peak oil" said:

> *"Don't know the estimated years for fossils to run out. It used to be 30 to 40 years now its 60 to 70 years, because no one seems to know the oil reserves accurately".*

While literature cites the push for biofuels in general and ethanol in particular as a response to either fossil depletion or climate change issues, the respondents linked the push for ethanol to fossil fuel shortages and the need to replace fossils with ethanol.

The finding is that fossil dependence reduction is a sustainability criterion. Congruence between this finding and literature was established although the “peak oil” did not feature highly as a reason.

4.5.1.6 Social welfare impact

A positive impact on social welfare resulting from ethanol production and use was considered a sustainability criterion by thirty out of thirty three, ninety one percent (91)%, respondents to the quantitative questionnaire on sustainability criteria (see Figure 4.5.2).

Jamieson (2011) submits that bringing employment and investment to poor rural areas is one of the reasons for the initial pursuit of biofuels in Africa. According to Van Zyl (2007), ethanol production boosts local agriculture production and opens additional markets and revenue for farmers, thus helping to generate employment and local economic growth.

A respondent with this view said ethanol production is

> *“a source of employment for the locals..”*

While another respondent expressed disappointment at

> *“the pace of Government, politicians, public treating ethanol as a peripheral component of the economy. Ethanol is key to economic independence”.*

The responses reflect the need for ethanol production and use to be viewed strategically as empowering rural communities through job creation on the path to economic independence.

A respondent highlighting the need for prioritising social spending argued against spending on fuel storage and captured it this way :

> *“Storage is a cost and there are working capital issues for example at the moment Government is building sixty (60) million litres of strategic storage at Matindi, Lilongwe and Mzuzu – this is roughly three months storage worth USD100 million (MK45 billion) in a country whose national budget is MK700 billion. Should we use that money for a “feel good factor” of storing fuel or spend the money to build factories and create jobs, and supply social services?”*

yet another respondent saw ethanol production and use as a means to uplift the lives of rural smallholder farmers and put it this way:

> *"I also already mentioned the involvement of smallholder farmers which will eventually change their economic livelihood. The biggest advantage is the benefit for the smallholder grower,.."*

The case for growing more energy crops for economic development and provision of employment is here made. Crop rotation of traditional food crops such as maize with energy crops such as sugarcane means more small farmers will work for money as opposed to just subsistence food farming (Orr et al., 2009).

Emergency management was cited as a social benefit coming from ethanol use as follows:

> *"Emergency vehicles army, police, ambulances and fire brigades can be put on ethanol which is grown locally to keep social services going".*

The finding is that the positive social impact of ethanol production and use is a sustainability criterion. The reasons given were mainly job creation and the economic empowerment of rural farmers which agree with the literature reviewed (Colares, 2008; Orr *et al., 2009;* Jamieson, 2011).

4.5.1.7 Land use change

Land use change (LUC) or indirect land use change (ILUC) posits that the rapid expansion of biofuel production in recent years is driving up the overall demand for agricultural land (Dunmore, 2011). This research investigated LUC via the sustainability questionnaire. Land use change or issues of food crop land shifting to energy crops had mixed responses. Fourteen out of thirty three (42%) thought land use change was not relevant while another thirteen (40%) were undecided and only six (18%) thought land use change was a sustainability criterion. The following sample responses reflect the spread of opinion.

One respondent had this to say on land use change,

> *" My understanding is that change from using the land in growing traditional food crops to using more land for cash/energy crops while implementing more efficient use of the dedicated land for food crops" [constitutes land use change].*

The idea expressed here was for food crop yields on dedicated land must increase in order to allow energy crops to develop. In section 4.3.2 a similar argument is advanced for energy crop yields to improve in order to release land for food.

Another respondent had a different view on land use change and is quoted as follows:

> *"Ethanol production cannot necessarily affect food production ... land used for ethanol feedstock is not automatically suitable for maize production"*

The recent agreement between the only sugar company and government for the sugar company to grow maize to help deal with the hunger issues seems to negate this view (Jimu, 2015). Under the agreement the sugar company will grow thirty seven hectares (37.7ha) of maize to assist government deal with the hunger emergency. This suggests sugarcane land is good for maize.

Another view on land said:

> *"The debate on jatropha land is a very lively one. Those on the biofuels side have sensible arguments as well as those against. I think in Malawi we have a lot of idle land – we like to make noise when someone begins to use that land. To me if the land is put to good use that is fine by me".*

There is a case of Jatropha, an energy crop, on ex-tobacco land cited in section 4.3.3. The debate referred to has to do with jatropha threatening to take up food crop land a thing which has not happened and is not likely to happen (Chittock, 2012). Heisy and Smale (1995), confirm that jatropha will not be allowed to displace food. Ellis et al. (2003), demonstrates that Malawi has land pressure due to the rapid population growth contrary to the respondents view. In Chapter 2, section 2.17.1 the case cited by Butler (2014) shows that arable land is becoming scarce. However Batidzirai (2007) presents that in the SADC (which includes Malawi) only a small fraction (5.5%) of available land is actually cultivated.

The mixed responses to the LUC reflect the reality in Malawi regarding the fact that energy crops grown as such occupy a very small portion of farm land. Sugar cane in Malawi is not generally viewed as an energy crop, but more as a food crop. The views on jatropha reinforce the author's view that LUC has not yet been defined as such in Malawi as explained in literature. Toleza farm is a jatropha farm which was a tobacco farm before, which is land use change but not as generally understood (Dyer et al., 2012). LUC literature as discussed has varying views on how to deal with perceived encroachment of energy crops on food crop land. There is disagreement on whether energy crops are in conflict with food crops to a significant degree (Chapter 2, section 2.17.1).

4.5.1.8 Analysis

Six criteria were chosen by the respondents as follows in their order of preference positive economic contribution, air quality improvement, positive forex effect, energy security improvement, fossil dependence reduction, and social welfare impact. The land use change (LUC) criterion had mixed responses.

According to the respondents positive economic contribution (or benefit) is the preeminent criterion for sustainable ethanol use (see Figure 4.5.2). This position contrasts with the EU reason for biofuel use and the 1986 Brazilian National Motor Vehicle Emissions Control programme raison d'etre, namely addressing GHG climate change issues (Chapter 2, section 2.18.1; Johnson and Silveira, 2014). It maybe postulated therefore that activities addressing issues of poverty are prioritized in the Malawi context. MERA (p.4, 2008) supports this conclusion by stating that ethanol use "*will enhance and improve rural livelihoods, welfare and also expand income generation opportunities".*

This research through the relevance rating (see Figure 4.5.2; Table 4.5.2) shows that in Malawi the GHG mitigation occupies second place as a criterion for sustainability unlike in the EU, Brazil and the USA where the reduction of GHGs is the primary reason for using biofuels (Chapter 2, section 2.18.1 to 2.18.5). According to the Environmental Affairs Department (2002) quoting the then Malawi President Muluzi, said "It is pleasing to note that the UNFCCC recognises that socio-economic development and poverty eradication are overriding priorities of developing countries". This agrees with the respondents' views that GHG issues are placed second in Malawi after poverty (section 4.5.1.2).

Ethanol use as a solution for forex shortages was considered a major sustainability criterion by ninety four percent (94%) of the respondents. The finding converged with literature (Chapter 2, section 2.17.1)

The respondents said that energy security is a sustainability criterion. The respondents' reason was that because Malawi is landlocked, there was therefore a need to have some control over fuel supplies and ethanol was seen as the solution consistent with the literature reviewed (Chapter 2,section 2.4.1).

The respondents agreed that reducing fossil fuel dependence is a sustainability criterion. Congruence between this finding and the literature reviewed was established although the "peak oil" did not feature highly as a reason (Chapter 2, section 2.4.1).

Respondents gave job creation and the economic empowerment of rural farmers as reasons for selecting positive social impact as a sustainability criterion, which agrees with the literature reviewed (Chapter 2, section 2.4.1; section 2.13.1; Colares, 2008; Orr *et al., 2009;* Jamieson, 2011).

4.6 Other findings

There are other findings which were established by the research. The other findings pertained to the significance of ethanol in the Malawi portfolio, strategic fuels reserves, synergies between ethanol and fossil fuels, estimates of optimal liquid fuels, government initiatives on ethanol uptake and potential contribution of ethanol to the economy. Specifically the research question asked in addressing these other findings was: "What should be done to make ethanol more significant in the Malawi liquid fuels portfolio?" Malawi imports approximately 100 million litres of petrol and 225 million litres of diesel (PIL, 2011).

Against this background, respondents (energy strategists) from the thirteen corporate energy organisations and central government departments were drawn into a quantitative type of discussion, for them to estimate what they thought would be an optimal volume of liquid fuels. Optimal portfolio refers to the total volumes of petrol, diesel, paraffin, aviation gas and biofuels that best fit the liquid fuel requirements of the nation at anyone given time (Chapter 2, section 2.2; Chen, 2013).

Issues of the relationship of ethanol volumes and fossil fuels particularly petrol were interrogated. Fuel storage emerged as an important item given the seasonality of ethanol production in Malawi and the fuel shortages in 2012, as well as government initiatives regarding ethanol (Sundu, 2012).

4.6.1 Strategic fuel storage

The questions posed to the thirty three respondents from the thirteen corporate energy organisations and central government departments was: "How do you think adequate fuel supplies can be assured in Malawi in the long term?" this elicited responses addressing the research question on actions required to make ethanol volumes significant and achieve an optimal liquid fuel portfolio.

The responses were varied but generally they pointed to the fact that Malawi needs adequate storage facilities for liquid fuels and for ethanol in particular if the country is to be assured of adequate supplies in the long term. Specifically fuel storage emerged as an important item given the seasonality of ethanol production in Malawi and the fuel shortages in 2012. The regulation requires all liquid fuel companies to hold ten days stock (2009 Liquid Fuels and Gas Regulations).

One respondent said there was a "need for a storage strategy for ethanol.." as a solution to long term adequate fuel supplies. He explained this need as follows:

> *"Need clear policies to compel, consumers, producers, investors etc to use blend consistently throughout the year. Currently factories run only six months a year no ethanol to blend in the rainy season.. Need storage strategy for ethanol to facilitate blend over the year".*

The seasonal nature of ethanol production occasioned by the sugarcane season means that six months a year there is no blending, he said. The NEP confirms this (Department of Energy Affairs, 2003, p.21). According to the respondent a storage strategy for ethanol is therefore needed.

Another respondent lamented the lack of strategic storage and expressed it this way:

> *"Interestingly the strategic reserves, there's no tank for ethanol because no one has it in their radar today. They don't even have a tank for paraffin because they think it is too small".*

The following question on volumes of imported fossil fuels was asked: "Given the estimated import volumes of 110 million litres petrol and 225 million litres diesel what do you think should be the volume of ethanol available?"

In response one respondent had this to say in explaining the need for strategic storage:

> *" it's a question of the authority [MERA] and Ministry of Energy reviewing [regulations] so that there should be a player in the market specifically for storage, no production, no blending but specifically [storage]. Where there will be an incentive for storage. There must be an incentive to [ethanol] industry. Incentives must be for independent storage, storage by industry beyond the 20% volumes and OMCs must have ethanol storage.*

According to this respondent, MERA and the parent Energy ministry should issue guidance for an independent storage entity to operate separately from existing ethanol industry storage facilities and OMC storage. He proposed incentives for storage volumes beyond the 20% blend mandate and argued that blending would then be possible all year as opposed to the current seasonal practice. NOCMA [National Oil Company of Malawi] a government fuel storage company was initially set up to include ethanol but that changed due to the terms of the donor partner, the government of India.

NOCMA was set up to address the storage issues nearly ten years after the National Energy Policy was published (Khanje, 2012). There are no plans to store ethanol at NOCMA.

Strategic storage reserves are mentioned as required for "reducing costs" and improving energy security (Department of Energy Affairs, 2003, p.21).

This discussion confirmed the gap noted earlier that the new company NOCMA did not have any plans for strategic ethanol storage (Chapter 2, section 2.7.4). Paraffin was also left out on the basis that volumes (15 million litres per year) were small.

The finding is that strategic ethanol storage is a pathway to making ethanol a significant part of the liquid fuels portfolio in Malawi. The regulation requires all liquid fuel companies to hold ten days stock (2009 Liquid Fuels and Gas Regulations). The regulations also provide for a storage levy whose purpose is to incentivise strategic liquid fuel storage for a minimum of ten days. The national ten days volume for petrol is approximately 300,000 litres (PIL, 2011). Ten days stock for ethanol would be 60,000 litres (sixty thousand litres) based on the 20% blend mandate and is achievable when in season (Chapter 1, section 1.5.1). However the fuel outages in recent years show that this is rarely achieved as confirmed by the respondents.

4.6.2 Synergies between Ethanol and fossils in the optimal liquid fuel portfolio.

Ethanol and fossil fuels co-exist in Malawi (Department of Energy Affairs, 2003). They use the same facilities including tanks at depot level and pumps for the blended petrol at selling points. This is different from the situation in Brazil and most western countries where ethanol has its own facilities. The fact that ethanol and fossil fuels co-exist suggests that there are synergies between them. Synergy simply means the interaction or working together of elements to produce a positive effect greater than the individual elements could muster (Dictionary.com, 2015).

The symbiotic relationship between ethanol and fossil fuel was investigated during the semi-structured interviews with the thirty three respondents from the thirteen corporate energy organisations and central government departments. The question posed was whether there were "any synergies between ethanol and fossil fuels". Thirty one respondents out of thirty three representing 94% confirmed that they saw synergies between ethanol and fossil fuels. Specifically they viewed ethanol as a substitute for petrol thus reducing the volume of imported petrol and facilitating the redeployment of the saved foreign exchange to other economic activity (section 4.5.1.3).

One respondent had the following to say:

> *"Ethanol came in as a fuel to reduce the import bill of the other fuel – this to me is wrong. It should be to reduce the cost of the final product sold, not necessarily as a substitute for the forex. It should be the reduction of the blended fuel, price. MERA pricing does not make sense. The OMCs do not have any incentive to buy ethanol with so many levies attached to it. Levies must be transparent".*

This minority view strongly suggested that ethanol was meant to reduce the fuel price to the consumers and not just as a foreign exchange saving measure. Price reduction in this case is based on the understanding that ethanol is cheaper than imported petrol and that the price differential should cascade to the motorist. This respondent seems to be putting emphasis on the synergetic relationships of pricing between ethanol and fossil fuels. He wants to see decoupling of the ethanol price from the petrol price for the benefit of the end user. In Malawi the lower ethanol price stops with the OMC and that is the way the market is structured in Malawi as the petrol sold is blended and ethanol is not sold as a standalone fuel (Extra Ordinary Gazette, 31st December, 2010).

Supporting the view of ethanol substituting for petrol one respondent had this to say:

> *"basically I don't understand why Malawi has not been able to emulate the Brazilian example whereby a substantial percentage of petroleum volumes that is imported have been replaced by ethanol in whatever form whether pure ethanol E20 or whatever X20s. I think ethanol can play a very substantial role…. I believe that ethanol and diesel can compliment each other quite well. As far as ethanol and petrol I believe one can substitute the other completely."*

The respondent explained that in Brazil ethanol is sold as a standalone fuel, then as a 20% blend with petrol (E20) and in various other blend ratios. He said ethanol and diesel can complement each other well because the bulk of diesel imported is for mostly for transportation and used for agriculture purposes. Malawi being an agricultural farming nation an ethanol diesel blend will enable farmers to cut down their fuel bill substantially if they blended diesel with ethanol (Chapter 2, section 2.7.3) . The assumption is that ethanol pricing is delinked from petrol (section 4.4.2). Pointing to the importance of substituting fossil fuels with ethanol one of the respondents from the thirteen corporate energy organisations and central government departments had this to say:

> *"..with the ethanol and fossil fuels [blend] Government could take up the proposed use of ethanol in terms of 100% and that would also assist the country in saving hard earned forex. And in doing so it would mean that most of the petrol driven vehicles would be now running on fuel ethanol as compared to the fossil fuels which is imported".*

The majority view (94%) was that ethanol should be a standalone fuel and its price should be significantly lower than petrol, resulting in less volumes of fossils being imported over time thus saving forex. Blending diesel with ethanol was seen as possible given the trials done with farm tractors in the 1990s (Chapter 2, section 2.7.1.3; Chaudhari, 2008).

The major finding in this section is that ethanol in the short term is seen as complimentary to fossil fuel and not a replacement. Some respondents argued that ethanol can be used for blending with the diesel. This view is aligned to the foreign exchange saving stance (see section 4.4.2.3). However in the long term ethanol was seen as a replacement of fossil fuels which are being depleted as revealed by the literature on “peak oil” (Crooks, 2013; Hubbert, 1956). In section 4.2.1.5 the reduction of oil dependence via biofuel use has been established as a sustainability criterion. As the oil reserves get depleted biofuels and ethanol in particular will move from being complimentary to being a replacement for fossil transport fuels. The discussion in Chapter 2 (section 2.3.2) shows that oil extraction is becoming more expensive and therefore driving the search for cheaper alternatives, among them biofuels. The symbiotic relationship between ethanol and fossils is therefore evident.

4.6.3 Estimates of optimal volumes of liquid fuels

In seeking to determine a possible optimal portfolio of liquid fuels the respondents were asked the following question during face to face semi-structured interviews: “Malawi imports approximately 110 million litres of petrol and roughly 225 million litres of diesel every year. Given these volumes what do you think should be the volume of ethanol available?” The respondents had various responses.

All (100%) the respondents were of the view that the blend ratio must be increased. Significantly many (60%) thought the blend mandate should go up to fifty percent (50%) suggesting that the volume for ethanol should be the same as for petrol.

Diesel blending had mixed responses showing that the practice is not as well-known and therefore not yet well supported. For example one respondent said:

> *I don’t know what volumes if you went 50/50 on petrol. I’m not sure whether you would be able to blend [ethanol] with diesel. So we should hit 100,000 half for petrol the rest for diesel.*

The volume of imported diesel was between 60% and 67% versus compared to the volume of imported petrol which was between 28% and 30% while the imported volumes for paraffin were bewteen 3% and 4% . It is significant that in this discussion the respondents did not see the issue of ethanol as a standalone fuel impacting the liquid fuel volume estimates.

The current volumes of petrol are estimated at 110 million a year while diesel volumes are at 225 million litres annually and paraffin stands at 15 million litres (MERA, 2014). The relative percentages are 64% diesel, 31% petrol and 4%

paraffin. Assuming the 20% blend mandate is being fully met the volume of ethanol will be 22 million litres. Respondents would like to see this volume increase to 55 million litres (50% blend mandate). The following response speaks to this

> *"But I think we should get the maximum. I understand the blending with petrol is 20% ethanol…if we can do more the better. It would be better for the economy of the country. Maybe 50:50".*

The projected liquid fuel portfolio with a 50% blend mandate for petrol without diesel blending would put petrol and ethanol at 55 million litres each annually. While diesel would remain at 225 million litres a year and paraffin would be at 15 million litres.

4.6.4 Government initiatives in ethanol uptake

The other determinants of a possible optimal portfolio of liquid fuels in Malawi are initiatives by Government in promoting ethanol uptake. In this connection, a question was posed as to whether or not Government is implementing any initiatives aimed at promoting the uptake of ethanol?

The responses were varied with nineteen out of the thirty three (58%) respondents saying "no" Government is not doing enough to promote the use of ethanol and the remaining fourteen (42%) who said "yes" Government is doing something to promote the use of ethanol in Malawi. It is noteworthy that none of the respondents saw the current blend mandate (law) as a government initiative. The fact that ethanol use as a blend with petrol, predates the law by twenty eight years, this may explain this silence (Chapter 2, section 2.6; Jumbe *et al*. 2007).

The government ethanol driven vehicle project (EDVP) was seen by the respondents as a positive initiative in increasing the uptake of ethanol. The Malawi Government approved in 2012 the use of flexi-vehicles in Malawi which requires that more ethanol be produced (Kambatata, 2012). Importation of these vehicles for the government fleet was approved in 2015 (Chinamulungu, 2015). The programme that led to this approval was the Ethanol Driven Vehicle Project (EDVP), research conducted by the National Commission for Science and Technology (NCST, 2011).

However, referring to the lack of progress on the EDVP a respondent said:

> *"I am disappointed by the pace of Government with regard to EDVP.EDVP dragging its feet. Private investors like … don't seem to have heart and soul in ethanol".*

Importation of flexi-vehicles first by government (as a pace setter) was seen as a necessary step in encouraging the acceptance and wider use of ethanol at consumer level. Since the approval in 2012 afore mentioned, government has not imported a single flexi-vehicle. In contrast Colares (2008) describes how the Brazilian government systematically legislated ethanol use initiatives including the introduction of the flexi vehicle. Citing the lack of seriousness another respondent from the corporate energy organisations and central government departments challenged government to:

> *"bring in flexi-vehicles for public transport and reduce commute costs for the public".*

A senior serving government official stated that the flexi-vehicle roll out is now scheduled for August 2015. Cabinet approval in Malawi does not mean a law has been passed. The approval for government to import flexi vehicles for its own use still has to go to parliament for it to become law. The finding here is that lip service is being paid for the flexi vehicle initiative by government.

In this section the researcher examined opportunities for achieving Optimal Portfolio of Liquid Fuels in Malawi. Storage facilities are very important if optimal levels of liquid fuels are to be achieved. Ethanol was established by the respondents as being complimentary to petrol in the short term and a replacement in the long term. The synergy is that as ethanol volumes increase in the liquid fuel portfolio the petrol volumes decrease and forex is saved both in the short and long term. The volumes recommended as optimal show a reticence towards quickly making ethanol standalone. Last but not least, the research has established that Government should be the prime mover of the agenda for promoting ethanol. Apart from paying lip service through workshops and conferences to the EDVP implementation there is not much that is being done by Government to promote the uptake if ethanol. The implications of nothing being done is that the Malawi ethanol program which has much promise will stagnate.

4.6.5 Potential Contribution of Ethanol to the Economy

The economic contribution of ethanol was probed by the following question: "*What is the potential contribution of ethanol to the economy?"* Specifically

Interviewees responded to three questions during the face to face semi-structured interviews. The questions posed were:

a) Ethanol production in Malawi has been going on for over 30years, has it made any difference?

b) Do you think it is advantageous or not to use ethanol as a fuel? Why?

c) Do you have information regarding diesel blending or experience with this type of blending? Would you recommend it for Malawi?

The discussion begins with the interviewees' perspective of the historical contributions of ethanol, followed by the responses interrogating the potential contribution under diesel blending specifically and economic contribution in general.

4.6.5.1. Historical Contribution of Ethanol in Malawi.

ETHCO was established in 1982 while PressCane began operations in 2004 (Chapter 1, section 1.5.1). This means that ethanol production and use have been going on for more than thirty years. In order to establish the contributions that ethanol has made to the Malawi economy in the past a question was posed as follows:

"Ethanol production in Malawi has been going on for over 30years, has it made any difference?"

Responses by the respondents were diverse as demonstrated by the sample answers quoted. Twelve out of thirty three (35%) respondents from the thirteen corporate energy organisations and central government departments agreed that ethanol had made a positive contribution to the Malawi economy. One respondent said:

> *"Yes because volumes of petrol are lower".*

Another respondent agreed but qualified the response as follows;

> *"Yes it has in terms of reduction in quantity of petrol [imported]. But as a country I don't think we have made a decision to increase the local market in other words local use of ethanol".*

The responses show that the volume of ethanol in petrol represents the fossil fuel volume substituted or replaced. However government's ambivalence is also recognized (Chapter 2, section 2.7.1).

The remaining twenty one respondents were of the opinion that the use of ethanol is not making any substantial contribution to the Malawi economy. One respondent had this to say:

> *"No difference, substantially, because the ethanol factories themselves use imported diesel for transporting raw materials and ethanol to market. Need these to convert to ethanol".*

Another respondent with a similar view put it this way:

> *"Not at all. Reducing the cost of fuel is a direct accelerator of economic growth. Because lowering the fuel price increases mobility in the country. This will reduce the price of commodities, reduce prices of services, so it will make a lot of difference. At the same time we must think about sustainability".*

These responses represent the view that ethanol has not made much of an impact on the economy. One reason given is that the ethanol industry is not doing enough to promote ethanol use as shown by the failure to use ethanol driven vehicles to move product to market and bringing in raw materials. The paradoxical situation of ethanol use for decades and the failure to grow its volumes is discussed in Chapter 2, section 2.7.1. Another reason pertains to the failure by government to reduce the cost of fuel. This suggests that government procurement or sourcing of fuel is not optimum resulting in high fuel prices which adversely affect commodity prices (see section 4.4.2). As noted before ethanol prices are pegged to the petrol prices. One respondent said that government procurement is not efficient and is quoted as follows:

> *"For good sustainable supply we need a good supply chain, financing with banks, to procurement, to choosing correct suppliers, good transporters, efficient delivery system. At the moment the supply chain is not efficient and there are costs that can be taken out".*

The divergence of views on this question is reflective of the failure by both the ethanol industry and government to fully harness the benefits of ethanol use to enhance the economy. The finding is that the long history of ethanol use has not benefited the Malawi economy as much as it should have.

4.6.5.2 Potential Contribution of Ethanol

The second question asked was:

"Do you think it is advantageous or not to use ethanol as a fuel? Why?"

The research sought to establish the awareness of the potential positive impact on the economy of fuel ethanol use. Literature is replete with advantages of ethanol use (Umbach, 2010; Fumo, 2009; Rastogi, 2011; Ahmad *et al*., 2013)

All, 100%, interviewees agreed that there were a lot of potential contributions that ethanol could make to the Malawi economy and that it was advantageous to use ethanol. The specific contributions that ethanol can make to the Malawi economy are many and varied (Chapter 2, section 2.19.1). They also include those emanating from the semi-structured interviews mentioned in the following paragraphs.

4.6.6 Diesel blending with ethanol

The investigation here sought to check whether or not the practice of blending diesel with ethanol is known, and whether or not there are potential benefits of this practice that would have a positive impact on the economy. A question was asked as follows:

"Do you have information regarding diesel blending with ethanol or experience with this type of blending? Would you recommend it for Malawi?"

Only one respondent had knowledge of diesel blending with ethanol and the views were captured as follows:

> *"In the past diesel blending was researched by Bunda [College of University of Malawi]. Tallow was used to deal (blend stabilizer) with moisture causing phase separation the only problem – this research needs to be reactivated.*

The lack of knowledge of diesel blending with ethanol was aptly put by one respondent as follows:

> *"Personally I thought you could only blend it [ethanol] with petrol not with diesel".*

The finding is that diesel blending with ethanol is a practice that is not well known. However the literature reviewed confirms that diesel can be blended with ethanol successfully (Chapter 2, section 2.7.3.). Löfvenberg (2007) discusses two types of diesel blends with ethanol diesohol and ED-diesel in Sweden. Diesohol is described as the first successful low blend (84.5% diesel, 15% hydrous ethanol and 0.5% emulsifier). "Demonstration tests [of diesohol] have also been performed in Thailand, Chile, Malawi, Germany, Brazil and in Sweden from 1993 to 1997" (p.7). The demonstration tests in Malawi took place in the 1990s as pointed out by one respondent and confirmed by Löfvenberg (2007).

4.6.7 Economic Contribution

According to PIL (2011), Malawi imported one hundred and ten (110) million litres of petrol in 2010. Given the mandated blend ratio of twenty percent (20%) ethanol in petrol the volume of ethanol required would be twenty two (22) million litres (Extra Ordinary Gazette, 31st December, 2010). In that year (2010) only nine (9) million litres of ethanol were actually blended out of the total eighteen and a half (18.5) million litres (Chapter 2, Table 2.6.1). The analysis in Chapter 1 section 1.9.1 and in Figure 1.9.1 shows the growth of this gap between actual ethanol volumes and the required volume for blending. This represents the potential volume of ethanol to be added to the liquid fuel portfolio. Table 4.6.7 shows the potential extra volume of ethanol for blending from 2004 to 2011.

Table 4.6.7: Potential Extra Volume of Ethanol for Blending

YEAR	20% PETROL	Ethanol (AA) actually blended	Potential Extra (AA)
2004	17,851,600	15,319,665	2,531,935
2005	16,475,400	11,104,492	5,370,908
2006	17,669,800	11,385,894	6,283,906
2007	18,428,600	8,986,741	9,441,859
2008	20,600,800	7,839,076	12,761,724
2009	21,275,200	6,489,818	14,785,382
2010	22,020,000	9,028,456	12,991,544
2011	18,528,000	11,723,167	6,804,833

Source: Author's analysis

A conversion of the 2009 extra ethanol volume of 14,785,382 litres (Table 4.6.7) into monetary terms at the production cost of MK 46 per litre (PressCane

Limited, 2009) of ethanol is MK 680,127,572 versus the FOB (free on board) price of petrol at MK 168.96 per litre. This represents a potential saving of MK1, 818,010,507 out of the fuel import bill that year of MK 32,316,177,509 (6%). The exchange rate in 2009 was MK148 to the United States Dollar (PressCane Limited, 2009).

According to National Bank of Malawi the 2014 exchange rate is about MK 400 to the United States Dollar (National Bank of Malawi, 2014). It must be noted that the ethanol market price in Malawi is regulated by MERA and is currently not related to the production cost. As mentioned before, the gap between the required ethanol volume and the actual produced for blending continues to increase (Chapter 1, section 1.9.1).

The other economic contribution of ethanol is foreign exchange saving. All fuels in Malawi are imported (NSO, 2011) and the 20% blend ratio of ethanol to petrol represents a maximum of 20% saving of foreign exchange (forex) on petrol imports.

Ethanol can contribute to a reduction of freight costs particularly considering that Malawi is land locked because it is geographically surrounded by Mozambique (south, east, west), Zambia to the west and Tanzania to the north and has no direct route to the sea (Chirwa, 2015; Robinson, 2009). Consequently imports have to be freighted long distances inland. Ethanol blending saves part of this freight bill to the extent that a volume of petrol is blended. Freight costs for petrol alone make up over 18% of the in bond landed cost (IBLC) (section 4.4.2, Figure 4.4.2).

The other economic contribution of ethanol is the reduction of dependency on imported petrol. Since ethanol is locally produced, it increases energy independence and improves energy security. Ethanol is a strategic commodity in case access to the sea ports is cut out by civil unrest in neighbouring countries, as happened during the civil war in Mozambique in the seventies (Robinson, 2009). Natural disasters such as floods can also cause disruption to fuel supplies as happened in the year 2000 in Mozambique (Davies, 2013).

Ethanol is produced from biological renewable sources, in this case sugarcane molasses. This is unlike depending on fossil fuels that are depleting with time (Umbach, 2010; Balat, 2008; Hubbert, 1956). Another potential economic contribution of ethanol is its use as an octane booster. Ethanol blend into petrol ups the octane rating (Ahmad et al., 2013). Malawi has a choice of importing lower-octane rating petrol and boost it up with ethanol blending. This would save Malawi significant expense since lower-octane fuels cost less per barrel than the high-octane fuels (Chapter 2, section 2.19.1). According to the Federal Trade Commission (2012), many petrol vehicles can run on lower octane fuel and do not need higher octane fuels. The difference in price between lower and higher octane fuels is quoted at between five cents and seven cents (USD) per litre (Federal Trade Commission, 2012).

A cleaner environment is good for health and reduces the national health bill. Incidents of asthma attacks, pneumonia, cardiovascular ills, and bronchitis are greatly reduced (Fischetti, 2011). Environmentally, the use of ethanol blends reduces carbon dioxide by promoting more complete combustion (Ahmad et al., 2013). There is a net reduction of carbon dioxide emissions into the atmosphere. Carbon dioxide is a normal product of burning fuels that contribute to global warming. Cane growing absorbs more carbon dioxide than is released by manufacturing and using ethanol (Herrera, 1997). Ethanol blended fuels reduce the net greenhouse gases thereby protecting the ozone layer and decelerating the global warming. There is therefore a major health benefit with cleaner air. This feeds into Government efforts to reduce the national budget for health. In some countries, users of environmentally sound technologies earn a grant from the Global Environmental Fund. This apart from environmental protection would also act as a forex source for Malawi.

Ethanol production has opened up employment opportunities for Malawians.
This is yet another economic contribution of ethanol. Ethanol Company (ETHCO) and PressCane Ltd are majority Malawian owned local companies. Small holder sugarcane growers have a chance of expanding their production as ethanol production grows (Chipukunya and Kacelenga, 2011). Ethanol production and use economically empowers small holder farmers (Chapter 2, section 2.13.1; Colares, 2008; Orr et al., 2009; Jamieson, 2011).

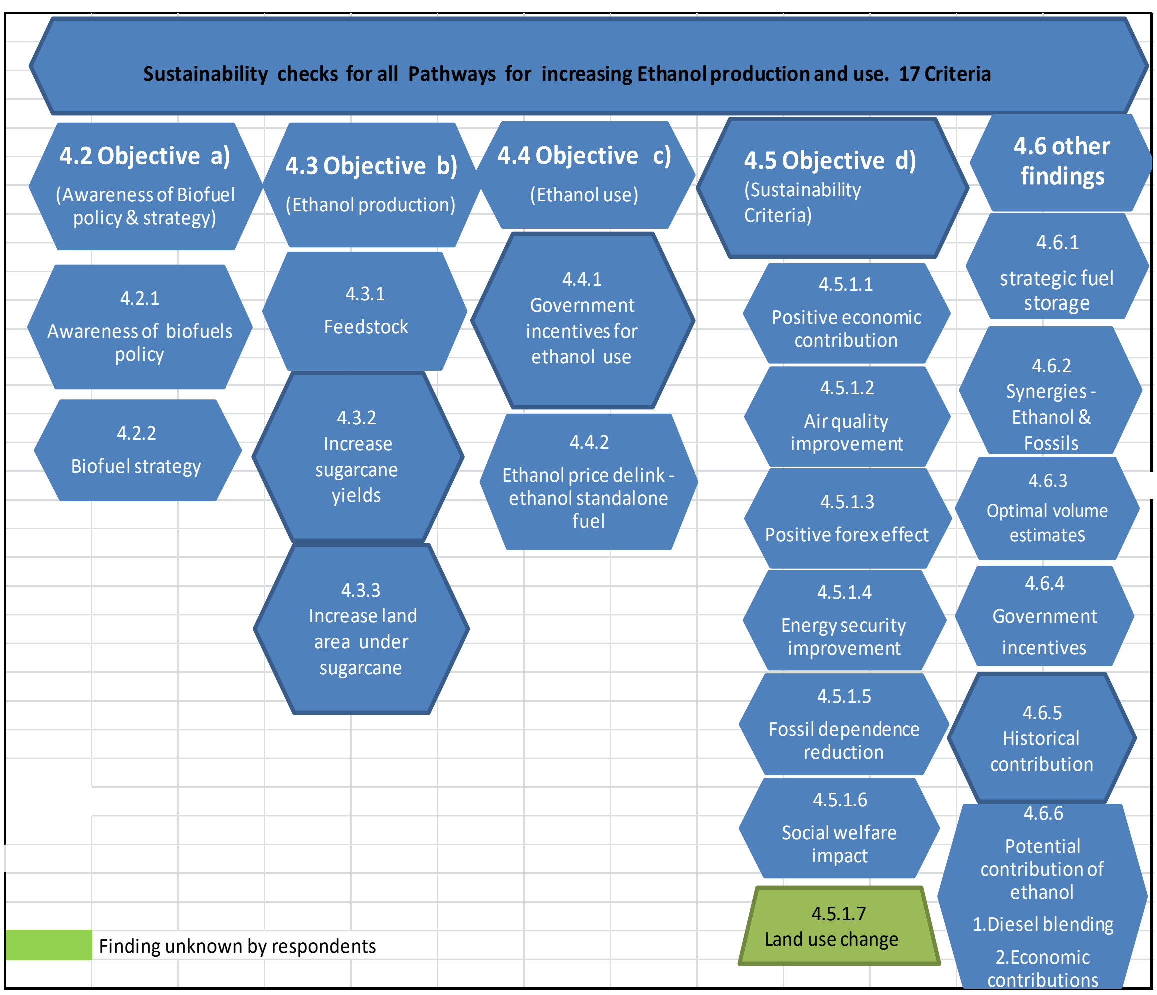
4.7 Summary

In chapter 4, a discussion on the findings from the semi-structured face to face interviews and questionnaire was conducted. Under the first research objective it was found that there is no biofuels policy or strategy that the interviewees were aware of.

The five pathways for increasing ethanol production and use in Malawi that emerged were next discussed. Seventeen sustainability criteria for ethanol production and use were ranked and the positive economic contribution criterion was seen as the most relevant by the respondents in contrast to the EU, Brazil, USA and elsewhere where GHG mitigation is number one. Three interventions for achieving an optimal liquid fuel portfolio and a sample calculation of the optimal volumes were discussed. Finally the historical and potential contribution of ethanol to the economy was discussed with diesel blending being cited as a major opportunity to be retrieved for promoting ethanol use.

Figure 4.7 shows the pathways for increasing ethanol production and uptake. These findings form the basis for the proposed framework presented in Chapter 5.

Figure 4.7: Summary of pathways to increase ethanol production.



Source: Author

Chapter 5:
The Strategic Framework for Malawi

5.1 Introduction

The goal of this research was to develop a strategic framework for sustainably promoting ethanol production and use thus making ethanol a significant part of the liquid fuels portfolio in Malawi. One desirable result would be to reduce fossil fuel dependence in Malawi (Kambatata, 2012; Robinson, 2009). From the outset it was established that the Malawi National Energy Policy does not contain a guideline for biofuels production and use (Jumbe *et al*. , 2007). However the paradoxical situation of the production and use of ethanol (a biofuel) for over thirty years prompted this research (Chapter 1, section 1.5.1).

From the research findings in Chapter 4, the framework for sustainably increasing the volume of ethanol in Malawi and making it a significant part of the liquid fuels portfolio emerges. Sustainability criteria were established by the respondents as a guideline for permissible biofuel, particularly ethanol, production and use pathways. There is a mixture of actions the ethanol industry can take directly and enablers by government and other stakeholders, such as the sugar industry and the OMCs (oil marketing companies).

The principal elements of the proposed framework are discussed in the following sections. The frameworks (lessons) discussed in Chapter 2 (section 2.18), for Brazil, India and the EU, are summarized in Table 5.1 and compared to the Malawi proposals. A brief discussion for each element now follows.

5.2 Biofuels policy items

The provision of a framework in the National Energy Policy for the development of ethanol in particular and biofuels in general was strongly urged by the respondents as a way of ensuring the growth of ethanol volumes (Chapter 4, section 4.2.1). A number of items for inclusion in such a framework were mentioned as follows:

5.2.1 Ethanol to be a standalone fuel

The majority of respondents said that ethanol should be declared a fuel in its own right (Chapter 4, section 4.5.2). This declaration in the NEP would encourage ethanol production and drive the growth of ethanol volumes. Brazil and the USA recognise ethanol as a standalone fuel while India and the EU have legislated various ethanol petrol blends (Chapter 2, sections 2.18.1 to 2.18.5). Xavier (2007, p.5), explains that “incentives were key to the rapid expansion of ethanol consumption in Brazil. In less than four years, ethanol production more than tripled”. Legislation of incentives aimed at encouraging ethanol use as a standalone fuel in Malawi could therefore realise similar transformation.

5.2.2 Ethanol awareness

Consumers would need to be aware that their petrol vehicles can run on ethanol consequently respondents proposed that government should embark on an awareness campaign for ethanol as a fuel (Chapter 4, section 4.2.2). This action would increase the demand for ethanol and drive up ethanol production thus achieving the desired result of increasing ethanol volumes in the liquid fuel portfolio. Johnson and Silveira (2014), confirm that expectations are important for consumer acceptance of alternative fuels such as ethanol, since reliability and performance are key concerns for car owners. An example of managing consumer expectations is the way the Brazilian government used a state owned company to make infrastructure investments for ethanol distribution in order to keep the cost of ethanol to consumers significantly cheaper than the cost of petrol thereby increasing ethanol visibility and uptake (Xavier, 2007). Active government intervention as opposed to relying on market imperatives alone is therefore recommended for Malawi.

5.2.3 Ethanol price and capping

The respondents stated that the ethanol price should be significantly lower than petrol to encourage ethanol uptake. A minimum of 30% was mentioned with the express aim of promoting ethanol use (Chapter 4, section 4.4.2).

In order to create an incentive for oil companies and fuel distributors, the price of ethanol has always been pegged slightly lower than the cost of imported gasoline (GoM, 2009). This gap is considered inadequate as an incentive by the respondents hence the recommendation. This contention is borne out by ETHCO's clear preference to discontinue the blending programme due to low profitability, but was pressured by the government to maintain the commitment with the rationale of energy security (CARD, 2012). Consumer expectations are that the ethanol price would be far lower than petrol hence increasing the uptake of ethanol. However this means lower profits for the ethanol producers suggesting that government would have to intervene possibly through incentives. An example of this is the EU where ethanol producer markets are guaranteed and excise duty exemptions for transport fuels are given to ensure producers make a profit (Bourguignon, 2015).

5.2.4 Ethanol diesel blending

Ethanol diesel blending was an unknown to the majority of respondents (Chapter 4, section 4.6.6). Literature however demonstrated that ethanol diesel blending is an existing practice that works (Chapter 2, section 2.7.3). Sweden is a leading successful case for ethanol diesel blending (Chapter 2, section 2.7.3). Demonstrations, in several countries including Malawi, with both hydrous (diesohol) and anhydrous ethanol blends (ED-diesel) date back to 1993 and have shown that various diesel ethanol blends can be used in diesel engines without any engine modifications (Löfvenberg, 2007, p.7). This is a practice that must be revived.

CARD (2012) says the Biofuels Association in Malawi initial focus was on oil based crops for diesel, particularly jatropha. This emphasis is understandable since the ethanol industry is well established. A more inclusive biofuels programme with extensive stakeholder involvement has now been established in both Brazil and Malawi, especially in their socially oriented biodiesel programmes (Hall et al., 2009; Wambua, 2011). Technical standards have been developed for ethanol and biodiesel through the Malawi Bureau of Standards, which is funded through fuel levies on energy products (MERA, 2009). Biodiesel is not, a blend with ethanol, but is a substitute for diesel which can be blended with diesel. The connection with ethanol is in the joint engagement of government and OMCs by the Association.

Inclusion of the diesel blending practice in the NEP would widen ethanol use and therefore promote ethanol production volume increases.

5.2.5 Blend mandate adjustment

The current blend mandate is 20% ethanol in petrol (Extra Ordinary Gazette 31st December 2010). Respondents recommended a gradual increase of the blend mandate (Chapter 4, section 4.2.2). This would increase ethanol use and production.

The blend mandate for nine out of the twenty nine states of India is 5% although the policy is targeting 20% by 2017 (Gonsalves, 2006; Shinoj et al., 2011). This is a case of gradually increasing the blend mandate. A similar approach has been taken by the EU where the blend mandate was 5.75% in 2010 and is expected to reach 10% by 2020. The respondents' proposal appears feasible with the cited precedents.

5.2.6 Ethanol strategic reserves

According to respondents there is no strategic storage reserve provision for ethanol and policy should specify such storage for ethanol (Chapter 4, section 4.6.1). The availability of ethanol storage means that ethanol availability would increase as opposed to the current seasonal trend occasioned by the sugarcane crop seasonality. The historical fact that fossil fuel supplies into Malawi have been disrupted is evidence presented by the respondents to justify the need for ethanol storage for running emergency vehicles such as ambulances and fire engines.

Robinson (2009) and Lea and Hanmer (2009) record fossil fuel disruptions due to wars outside Malawi thus lending credence to the necessity for strategic storage for fuel generally and ethanol in particular as pointed out by the respondents. High oil prices are especially serious for a landlocked oil-importing country such as Malawi, affecting the prices of all imported goods and the costs of getting their own products to export markets.(Johnson and Silveira, 2014). Strategic storage would mitigate these price shocks. According to Gonsalves (2006), to establish biofuel trade, the infrastructure for biofuel transport, storage, blending and distribution of biofuel must be created from scratch.

5.2.7 Energy crops

Energy crops mentioned by the respondents included cassava, sweet sorghum, and potatoes besides sugarcane. Literature mentioned sugar beet as well. Maize, potatoes and cassava were however consistently ruled out as being food crops in Malawi due to the starch based diet (Chapter 4, section 4.3.1). Respondents felt that the biofuels policy must specify which crops maybe used for energy and which ones not. Soya was cited as an example, from the food security policy, of a crop not allowed for energy production.

Chunga (2015) says there is looming hunger in 2015 in Malawi due to a shortage of maize and this demonstrates that maize is excluded from ethanol production. According to Balat (2008), 80% of China's bioethanol production is grain-based, mainly derived from corn, cassava and rice. Sweet sorghum and tropical sugar beet are also listed as energy crops for ethanol production and not classified as food in the Indian context (Gonsalves, 2006). The EU biofuel policy allows rapeseed, maize, wheat and sugar beet as energy crops (Bourguignon, 2015) while the Indian Biofuels Policy is more explicit in excluding food crops from doubling as energy crops (Shinoj et al., 2011). The respondents' recommendation is for a biofuel policy that is explicit regarding the exclusion of food crops, particularly maize, from ethanol production.

5.2.8 Emissions control

In the context of the green belt initiative, respondents said that government should "add value to effluent" (Chapter 4, section 4.2.1). Apart from regulating effluent discharge the thought was that effluent should be converted into something useful such as fertiliser or stock feeds in the case of vinasse (effluent from ethanol processing). The use of water conservation or reclamation technologies to manage vinasse (waste) disposal to improve ethanol yields was another value adding measure mentioned. Existing effluent recycling technologies were cited as a reason for government to engage the industry in procuring these through climate change grants (Chapter 4, section 4.2.1). Carbon dioxide emissions were mentioned as an effluent with opportunity (Chapter 4, section 4.2.2; IEA, 2013).

Other value adding “co-products” mentioned in literature include fertiliser from ethanol processing expended phosphates and urea (Cornland *et al*., 2001). According to Johnson and Silveira (2014), a biogas plant in Malawi meant to capture methane funded by the Dutch government was a failure in the 1990s. However this is being revisited in order to capture and beneficiate methane gas emitted from the vinasse waste (Khatiwada and Silveira, 2011). The Brazilian and EU biofuels policies target GHGs (carbon dioxide emissions) primarily and do not cover the other emissions mentioned here (Xavier, 2007; Bourguignon, 2015). The respondents’ recommendation is for a biofuels policy that is more encompassing on biofuel effluent control.

Items for inclusion in a Biofuels policy as suggested by respondents have been discussed. The cited country cases point to possible actions that can be taken by government or industry. The following are recommended actions for government to operationalise policy.

5.3 Recommendations for Government actions.

Incentives to encourage ethanol production must be provided initially by the government. Over the long term, fuel companies should experience the benefits of using the ethanol blend and thus government intervention would give way to the market forces (Chapter 2, section 2.14.5; Mitchell, 2010). A range of actions have emanated from the detailed findings (section 5.2).The proposed actions by government are summarized in the following.

5.3.1 Lower ethanol price

The end user of ethanol will benefit if the price of ethanol is lower. According to the findings the current price of ethanol in Malawi is too high (Chapter 4, section 4.4.2). The ethanol industry could take the lead in reducing the price since government normally specifies the maximum. On the other hand government could significantly increase the price differential between ethanol and petrol as recommended by the respondents (section 5.2 c).

5.3.2 Delink the price of ethanol

Another ethanol price related recommendation is that government should delink the ethanol price from petrol (Chapter 4, section 4.4.2). Again the effect is that the blended fuel will have a lower price for the benefit of the end users. In the end more ethanol will be consumed thus increasing ethanol use. The increased demand will drive increased supply.

5.3.3 Reduce or remove levies on ethanol

Currently ethanol is not a stand-alone fuel, consequently the levies that apply to petrol affect ethanol resulting in a high ethanol price (Chapter 4, section 4.4.2). The recommendation to remove or reduce levies on ethanol follows when the ethanol price is delinked from petrol.

5.3.4 Input subsidy for small holder farmers

Sugar cane farming in Malawi is mostly done by estates owned by one company (Chapter 1, section 1.5.1). Small holder farmers have to sell their sugarcane to this company at given prices. The recommendation is for government to support the small holder sugarcane farmer via an input subsidy programme (Chapter 4, section 4.4.1). This would increase sugarcane production and in turn the volume of molasses the raw material for ethanol production. It has been noted that subsidies are a thorny issue for government development partners (Chapter 4, section 4.4.1; Gondwe, 2014). The recommendation suggests that subsidies must be a permanent feature (Chapter 4, section 4.4.1; Chapter 2, section 2.3.4; Chibwana and Fisher, 2011).

5.3.5 Duty free status for ethanol production equipment

The findings single out fuel ethanol production equipment for duty free status by government (Chapter 4, section 4.4.1). This would encourage ethanol producers to expand capacity and thus spur the increase in volumes for fuel ethanol produced.

5.3.6 Flexi fuel vehicle imports

The action recommended is for government to import flexi fuel vehicles because it has the largest fleet of vehicles (Chapter 4, section 4.4.2). As already described these are vehicles which can run on one hundred percent (100%) petrol, or one hundred percent (100%) ethanol or on a blend (Ahmad *et al*., 2013). The rationale is that if the government fleet is “flexi”, car dealers would follow suit and ethanol uptake would increase. Respondents recommended that the ethanol industry and OMCs should install two dedicated ethanol pumps in each of the main cities of Blantyre , Lilongwe and Mzuzu as an initiative to increase ethanol uptake (Chapter 4, section 4.2.2) .

5.3.7 Duty free status for conversion kits.

Older vehicles made before the year 2000 would have issues with using fuel ethanol due to its corrosive nature (Anh-Thu and West, 2004). This would be mitigated by retrofitting conversion kits to enable these vehicles to run on fuel ethanol. The recommendation from the findings is that these conversion kits be accorded duty free status to incentivise owners of old cars to use ethanol (Chapter 4, section 4.4.1). This in turn would increase the uptake of ethanol.

5.4 Feedstock

The majority view on sugarcane was that it should be seen as an energy crop. A clear link was established between the lower than desired ethanol volumes and the availability or lack of feed stock (raw material). The existing gap between the required volumes for the 20% (twenty percent) blend mandate would be addressed by increasing feedstock (Chapter 4, section 4.3.1). Recommendations were made by the respondents for actions to close the gap of required blend mandate volumes caused by the lack or unavailability of feedstock. The recommendations are summarised in the following sections:

5.4.1 Grow more Sugarcane.

More sugarcane should be grown specifically as an energy crop. The findings show that an increase in the area under sugarcane will lead to higher ethanol volumes. This therefore becomes a pathway for growing the volume of ethanol in the liquid fuel portfolio. The use of molasses a sugar production waste or by product seems to sidestep the food versus fuel debate (Chapter 4, section 4.3.3).

Growing sugarcane in Malawi is not hitherto a government activity. However the green belt initiative is meant to increase sugar production and therefore molasses (Government of Malawi, 2011). The primary implementing agency for this strategy is the government via GBI which also includes smallholder farmers.

5.4.2 Increase sugarcane yields

Increasing the volume of ethanol via improved sugarcane yields is a strategy found in literature but was not raised by the respondents (Chapter 4, section 4.3.2). Comparisons of Malawi sugarcane yields with other countries in the region show that there is a gap to close in this respect (SADC Sugar Digest, 2014).

The government research agency NCST and the Sugar Industry should lead this endeavour.

5.4.3 Develop other energy crops

According to the respondents during the semi-structured interviews other crops were seen as possible feedstocks (Chapter 4, section 4.3.2). The crops mentioned had caveats regarding their use. Soya bean was mentioned but was said to be in the as yet undocumented food security policy as banned from any use other than for food. Maize, potatoes and cassava the other possibilities were overwhelmingly excluded because in the words of one respondent "because our diets [are] starch based". The only crop apart from sugarcane mentioned as a possible energy crop without any caveat was sorghum (Chapter 4, section 4.3.1). There is therefore a need to develop more energy crops in Malawi as a pathway to increase ethanol volumes.

5.5 Flexi vehicles

Respondents urged government to change policy and change the government fleet to flexi vehicles with a view to use ethanol as a fuel. This would result in increased use of ethanol. The rationale, as mentioned in section 5.3.6, was that government has the largest fleet and this would encourage car dealers to import more flexi vehicles (Chapter 4, section 4.6.4). As noted before government has made pronouncements agreeing with this recommendation but no action has occurred (Chapter 4, section 4.6.4)

5.6 Research ethanol yields and recoveries

Ethanol is produced from a variety of feedstocks but sugarcane continues to be the feedstock of choice (Chapter 4, section 4.3.1). Improvements in the sugar content, specifically cellulose means higher ethanol volumes (Chapter 4, section

4.3.2). Technologies, as observed by the respondents, exist where other starch crops such as cassava can be broken down into monosaccharides and disaccharides to produce sugar and hence molasses, although cassava was excluded due to fuel versus food concerns (Chapter 4, section 4.3.1). In the following sections a summary of the research areas is given.

5.6.1 Ethanol extraction yields.

Improvement of ethanol extraction yields was not mentioned by the respondents; however literature indicates the desirability of such research (Chapter 2, section 2.14.3). Equipment suppliers do have research and development divisions (Chaudhari, 2008). These development divisions ought to be used to improve ethanol extraction yields.

5.6.2 Ethanol recovery.

The recovery of ethanol from effluent was cited by respondents as a way of increasing ethanol volumes (Chapter 4, section 4.3.1). Government was urged to access global climate change funds to lead research and development activities in this area (Chapter 4, section 4.2.1). The use of existing reclamation technologies is encouraged in order to develop more efficient ones (European Parliament, Council, 2009). Apart from the benefit of increasing ethanol volumes such recovery simultaneously reduces the volume of effluent discharged.

5.6.3 Biotech research

Literature cites the need for biotech research in order to increase the availability of feedstock (Chapter 4, section 4.3.1). Although respondents did not mention this aspect it follows that increasing feedstock per hectare of land translates into higher ethanol production volumes. This is therefore a legitimate pathway for increasing ethanol volumes and is a long term solution.

Table 5.1 Frameworks compared to Malawi proposals

Country Region / Element	MALAWI proposals	BRAZIL	INDIA	EU
Biofuels Policy	There's no policy. Need a policy embedded in NEP.	Proalcool 1975 & National Motor Vehicle Emissions Control 1986.	Indian National Policy on Biofuels 2009.	Directive 2009/28/EC
Biofuel policy elements	a) Ethanol to be standalone fuel. b) Biofuel awareness c) Pricing of biofuels d) Blend mandates e) Strategic storage f) Energy crops	a) Ethanol is a standalone fuel. b) Very visible c) 65% cap on ethanol. d) Ethanol petrol blend 25% e) Fuel reserves f) Sugarcane dominant.	a) Ethanol blends only. b) Nine states only c) Farmer subsidy. d) 5% mandate e) Fuel storage f) Sugarcane & Jatropha being	a) Ethanol blends only b) Actively promoted. c) Producer markets guaranteed d) Blend mandates 5.75% increasing e) Strategic reserves f) .Rape seed & sugar

	g) Emissions control	g) Policy targeted.	supported. g) Not in policy. Policy targeting fossil independence and energy security.	beet g) GHG emissions targeted.
Government incentives	a) Lower Ethanol price. b) Fuel levies remove c) Sugarcane farmer subsidies. d) Duty free status for ethanol production equipment. e) Flexi vehicle introduction	a) Guaranteed: ethanol price lower than petrol. b) Reduced taxes on ethanol vehicles. c) Sugarcane grower subsidies. d) Distillers' subsidies. e) Manufacture of flexi cars & tax breaks for flexi vehicles.	a) Ethanol price is free market. b) No taxes on sugarcane proceeds. c) Sugarcane grower subsidies. d) No distillers tax breaks. e) None	a) Market price subsidies. b) Production subsidies. c) No energy crop subsidy d) Production subsidies. e) Excise tax exemptions on transport fuels.

Feedstock	a) Grow more sugarcane b) Increase sugarcane yields. c) Develop other energy crops	a) 35% more sugarcane area in 70 years. b) Yields up by 43% in 70 years. c) Cassava not successful.	a) Sugarcane area restricted by food / fuel policy issues. b) Yields stagnant. c) Jatropha, sweet sorghum, sugar beet.	a) No sugarcane in EU. Energy crops rapeseed, soya, maize. b) Yields of rapeseed etc also save on land use. c) Pursuing agriculture wastes – cellulose.

Research	a) Ethanol Yields b) Recoveries c) Biotech for improved yields	a) Over 100 new high yield varieties. b) Yeast recovery c) Technical development through ProAlcool.	a) Need to improve ethanol technology b) Low recovery, needs improvement. c) Boitech research targeting enzymes for cellulose	a) Targetting cellulosic yields b) EU preference for recycling and not recovery. c) Focused research on cellulose

Source: Author

Table 5.2 is derived from the findings in chapter 4 and is the summary of the framework discussed in this chapter.

Table 5.2: Strategic framework: Sustainably promoting ethanol production and use

Pathways	Actions	Rationale	Action by
1) Biofuels policy items	a) Make ethanol a stand-alone fuel.	Encourage ethanol production.	Government.
	b) Public awareness campaign for ethanol.	Final consumer benefit.	Ethanol industry and Government.
	c) Cap ethanol price not to exceed 65% petrol price.	Increase ethanol uptake.	Government.
	d) Include diesel blending with ethanol.	Widen ethanol use and uptake.	Government.
	e) Mandatory strategic ethanol storage reserves for large-scale fuel importers.	Enhance energy security	OMCs & Government
	f) Specify energy crops for biofuels & land criteria.	Managing food versus fuel issue.	Government.
	g) Effluent regulation	Add value to effluent and produce other products. Provide legal framework in NEP for ethanol development particularly &	Government through environmental affairs department.

		biofuels in general.	
2).Government incentives	a).Lower ethanol price – end user benefits. b) Change pricing formula for ethanol – delink ethanol price from petrol. c) Reduce levies on ethanol d) Input subsidy for small holder sugar cane farmers – increase raw material. e) Duty free status for ethanol production equipment and spares. f) Policy to import flexi vehicles for government fleet – government has largest vehicle fleet. g) Duty free status for conversion kits for older vehicle makes – end user can switch to ethanol use.	Ethanol use increases thus encouraging growth of production volumes.	Government & Ethanol Industry
3) Feedstock increase	a) Grow more sugarcane as energy crop.	Gap between ethanol volume and 20% blend	Sugarcane industry & Government.

	b) Increase sugarcane yields per hectare. c) Develop use of other crops e.g. sorghum to compliment sugarcane. d) Policy against use of maize	mandate resolved,	Research in sugar industry and Government (NSTC)
4) Flexi fuel vehicles	a) Government to implement EDVP recommendations as a pace setter for the auto industry.	Increase local market for ethanol.	Government
5) Research ethanol yields & recovery.	a) Improve ethanol extraction methods b) Reduce effluent volumes to stem ethanol losses to effluent. c) Biotech research to increase sugarcane yields per hectare and sugar content in cane.	Research ethanol production yields and recovery methods in order to grow the volume of ethanol.	Ethanol industry. Ethanol industry NSTC & Sugar Industry

5.7 Summary

In this chapter, the various pathways for increasing ethanol suggested by the respondents in chapter 4 have been summarized. A framework based on these findings has been proposed in Table 5.2. The framework is a result of the respondents recommendations regarding sustainable pathways to strategically increase ethanol production and use resulting in the reduction of fossil fuel use.

Chapter six presents the conclusions of this research. The objectives of the study are summarized. Most importantly the theoretical and practical contributions are articulated.

Chapter 6
Conclusions

6.1 Introduction

The title of this research: "Towards an Optimal Portfolio of Liquid Fuels for the Malawi Energy Market: A Study to develop a strategic framework for ethanol production and use " reflects the area this research has contributed knowledge to. The research was conceived against the backdrop of an ever increasing gap between the mandated twenty percent volume ethanol to eighty percent petrol versus the actual ethanol volume blended as shown in Figure 1.9.1 (Chapter 1, section 1.9.1). The goal of this research was to develop a strategic framework for sustainably promoting ethanol production and use in order to make ethanol a significant part of the liquid fuels portfolio and reduce fossil fuel dependence. The purpose was to find pathways for increasing the production and use of ethanol in Malawi. The specific objectives of the research were to:

a) Determine the level of awareness on biofuel policy and strategy.
b) Find pathways of increasing ethanol production to make it significant in the liquid fuel portfolio.
c) Find pathways for increasing the use of ethanol to make it significant in the liquid fuel portfolio.
d) Investigate sustainability criteria for ethanol production and use.

In the quest to achieve the goal, purpose and objectives, the research sought to answer the following overall question: "How can the production and use of ethanol be sustainably increased in order to reduce dependence on fossil fuels in Malawi?" The specific key questions that needed to be answered in this research are:

a) What policies exist to coordinate bio-fuels and fossil fuels?
b) What should be done to make ethanol more significant in the Malawi liquid fuels portfolio?
c) How can the use of ethanol be increased?
d) What criteria should be considered in determining biofuel sustainability?

The overall conclusion of the research is that "yes" both the production and use of ethanol can be increased as long as there is the political will to do so by promulgating policies that can support that initiative. The guide to do so is contained in the strategic framework that this research developed in chapter five (see Table 5.2).

The chapter begins by restating the research goal and purpose, followed by the recommendations emanating from the findings under each objective, other findings and recommendations are presented, followed by conclusions on the theoretical and practical contributions to knowledge particularly the strategic framework developed. Then the limitations of the research and finally areas for further research are highlighted. A short summary closes this chapter.

6.2 Goal of the Research

The goal of this research was to develop a strategic framework for sustainably promoting ethanol production and use to make ethanol a significant part of the liquid fuels portfolio and reduce fossil fuel dependence in Malawi was achieved. The researcher ably developed a strategic framework for Malawi in chapter five. There was no need to adjust the goal. When the provisions of the framework are operationalised, Malawi is likely to have increased ethanol production and use. The framework provides for the following:

a) A biofuels policy
b) Government incentives for biofuels, particularly ethanol production and use
c) Increasing feedstock for biofuels particularly ethanol production and specifying feedstock types
d) Introduction of flexi fuel vehicles (FFVs)
e) Research into ethanol yields and recovery

6.3 Purpose of the Research

The purpose of the research as defined in chapter 1 section 1.11 was to find pathways for increasing the production and use of ethanol in Malawi. The purpose of the research was achieved because the research managed to identify pathways for increasing ethanol production and use in Malawi.

6.3.1 Pathways for increasing production that were identified include the following:

a) increasing feedstock options, and

b) increasing land under sugarcane.

c) The third pathway was noted in the literature review as increasing sugar cane yields.

6.3.2 Pathways for increasing use of ethanol include the following:

a) Government incentives such as subsidies for smallholder sugarcane farmers, tax breaks for FFV imports, and ethanol manufacturing equipment.

b) Delinking the price of ethanol from petrol and removal of levies

6.4 Objectives and findings of the research

Four objectives were defined in chapter 1 section 1.11.

In this section the researcher presents recommendations from the findings for each one of the objectives.

6.4.1 Objective a): Determine the level of awareness on biofuels policy and strategy.

The first objective was to determine the level of awareness on biofuels policy and strategy. The research revealed that the target audience is not aware of the existence of a biofuels policy or strategy. The polices and strategy are not documented in the NEP or anywhere for Malawi in spite of the practice of blending petrol with ethanol being in existence for over thirty years (Chapter 4, section 4.6.5.1). The absence of a biofuels policy and strategy has had negative consequences such as failure to achieve an optimal liquid fuels portfolio. Remedial action recommendations by the respondents are:

a) Government developing a policy to coordinate ethanol and fossil fuels.

b) Government declaring ethanol a standalone fuel.

c) A tax reduction and removal of levies by government.

d) Government accessing global funds to lead industry in research and development activities.

e) The blend mandate increasing gradually.

f) Government importing flexi fuel vehicles.

g) Industry leading in making ethanol visible to end users by setting up pilot ethanol filling stations in major cities (chapter 4, section 4.2.1).

The recommendations by the respondents point to the need of a visible policy and strategy in the development of ethanol production and use. Awareness of the biofuels policy and strategy was included as a pillar of the strategic framework to sustainably increase the production and use of ethanol.

6.4.2 Objective b): Find pathways of increasing ethanol production.

Under objective b) which is to determine how to increase ethanol production in order for it to become significant in the liquid fuel portfolio, the research identified pathways to increase ethanol production volumes. Three pathways were identified by the research for increasing ethanol production in Malawi and are briefly reiterated in the following sections.

a) Feed stock production increase.

According to the findings of the research increasing and diversifying feedstock will increase raw material for ethanol production. Energy crops recommended were sugarcane and sweet sorghum. Maize was emphatically excluded.

b) Increase sugar cane yields.

The research showed that sugarcane yields can be dramatically increased. This reduces the need for more land as the ethanol volumes increase and mitigates LUC issues.

c) Increase the land area under sugarcane.

More land under sugarcane is directly related to higher ethanol production volumes. The finding suggested switching former tobacco land to sugarcane farming as a response to the land for fuel taking up land food concern.

The pathways identified constitute an important part of the strategic framework for sustainably promoting ethanol production and use (Chapter 5, Table 5.2). Ethanol then becomes a significant part of the liquid fuels portfolio in Malawi.

6.4.3 Objective c): Find pathways of increasing ethanol use.

Two pathways were identified as leading directly to increased use of ethanol and indirectly to ethanol demand and production. These pathways were government incentives and ethanol price delinking as succinctly stated in the following sections.

a) **Government incentives via selected subsidies**

Subsidizing smallholder sugarcane farmers was seen as a way to increase raw material for ethanol production (Chapter 4**,** section 4.5.1.6). Subsidies on ethanol production equipment and removal of levies on ethanol would encourage ethanol production and thus increase ethanol volumes.

b) **Ethanol price delinking from the petrol price**

The research showed that declaring ethanol a standalone fuel in tandem with delinking its price from the price of petrol would increase ethanol use (Chapter 4**,** section 4.4.2). This increased demand would in turn spur higher ethanol production volumes.

The pathways identified by the respondents are embedded in the strategic framework for sustainably promoting ethanol production and use (Chapter 4, Figure 4.7; Chapter 5, Table 5.2).

6.4.4 Objective d): Investigate sustainability criteria for ethanol production and use.

The goal of this research was to develop a strategic framework for sustainably promoting ethanol production and use. The pathways for increasing ethanol production and use included in the strategic framework must be sustainable (Chapter 4, section 4.5). Therefore the fourth objective aimed at investigating the sustainability criteria for ethanol production and use. According to Purchas and Hutchinson (2008, p.5) sustainability is "the ability to produce biofuels to contribute to today's fuel needs without compromising the ability of productive land to meet current and future food and fuel needs" (Chapter 4, section 4.5).

The sustainability of biofuels production and ethanol in particular in light of the perceived competition for land and other resources between food and fuel has led to the development of various sustainability frameworks and criteria. The research identified the relevant criteria for Malawi. Six criteria were rated highly (Chapter 4, section 4.5). These were as follows:

a) Positive economic contribution.

The extra volume of ethanol in the liquid fuel portfolio constitutes an economic benefit first by increasing the volume of fuel available via blending with petrol. Second by providing a cushion for the fossil fuel price volatility the economy is positively impacted. This criterion was rated the most important (Chapter 4, section 4.5.1.1)

b) Air quality improvement (reduction of GHGs)

Air pollution is attributed to harmful emissions of gases particularly carbon dioxide from transport fuels GHGs). Ethanol is proven to reduce these gases and therefore improves air quality (Chapter 4, section 4.5.1.2). This criterion was rated the second most important.

c) Positive forex effect.

All fossil fuel is imported into Malawi. The fuel import bill is the highest on the list of imports, it was 16.5% in 2010 (NSO, 2011). Ethanol reduces the volume of fuel that must be imported and thus reduces the requirement for forex. This criterion was rated the third most important (4.5.1.3).

d) Energy security improvement.

Energy security was rated the fourth most important criterion. Because Malawi is landlocked, there is a need to have control over fuel supplies and ethanol is seen as a solution. The case in 1979 where conflict in neighbouring Mozambique interrupted fuel supplies underlines the potential energy security provided by the use of ethanol (Robinson, 2009).

e) Fossil dependence reduction.

Over eighty percent of fuel used is imported fossil fuels. Ethanol provides the route to a reduction of the volume of fossil fuel imported and therefore a reduction on fossil fuel dependency. This was the fifth most important criterion.

f) Social welfare impact.

Ethanol use is associated with mainly job creation and the economic empowerment of rural farmers (Colares, 2008; Orr *et al., 2009;* Jamieson, 2011).

This positive impact on social welfare was found to be the sixth most important sustainability criterion. Literature indicates this as the reason for the initial pursuit of biofuels in Africa (Chapter 4, section 4.5.1.6).

A significant finding here was that economic contribution was rated the highest contrary to EU and Brazil where reduction of GHGs (air quality improvement) is primary (Chapter 4, section 4.5.1.2).

The land use change criterion had mixed responses. It was discussed because it is a global talking point that could have implications for Malawi given that the EU has in the past been a market for Malawi ethanol (Chapter 4, section 4.5.1.7).

6.5 Notable Findings of the Research

The following are the notable findings of the research.

6.5.1 Response to 1973 OPEC embargo

The first one is the petrol to ethanol blending response of the selected countries and regions and Malawi to the 1973 OPEC oil embargo. However, the other countries went on to develop frameworks on biofuels for example, Brazil responded by developing ProAlcool, while the USA had periodic FARM Bills and the EU had the Directives on biofuels. Malawi on the other hand had no framework for biofuels at all (Chapter 2, section 2.18).

6.5.2 GHG targeted by frameworks

A second notable finding is that later most of the selected countries and regions targeted their ethanol frameworks at reducing the levels of GHGs while India and Malawi focused their ethanol blending activity on economic development.

6.5.3 LUC in Malawi

A third notable finding is the fact that in Malawi the LUC (or ILUC) was not seen as an important sustainability criterion. The mixed responses to the LUC reflect the reality in Malawi regarding the fact that energy crops grown as such occupy a very small portion of farm land. Sugar cane in Malawi is not generally viewed as an energy crop, but more as a food crop (Chapter 4, section 4.5.1.7).

6.5.4 Sustainanbility criteria in Malawi

Fourthly out of the seventeen biofuels sustainability criteria recognized in the selected countries and regions only six had relevance for Malawi according to the relevance rating by the respondents (Chapter 4, Table 4.5.2).

6.5.5 Diesel blending

Diesohol demonstration tests were carried out in Thailand, Chile, Malawi, Germany, and Brazil and in Sweden from 1993 to 1997. Sweden actually blends diesel with ethanol while Malawi does not in spite of being one of the first test countries.

6.6 Other findings

In the course of the semi-structured interviews questions were asked in relation to the fossil fuel volumes in Malawi relative to ethanol. A question was asked as to whether ethanol was a replacement or complimentary to the fossil fuel. The economic contribution of ethanol was also interrogated. The benefits of ethanol use form a significant part of the strategic framework for increasing ethanol uptake and are highlighted. The following sections summarise these findings.

6.6.1 Optimal fuel volumes

Petrol and diesel consumption figures for 2011 (PIL, 2011) were presented in a bid to obtain from the respondents what they saw as optimal volumes of petrol and diesel fuel and what they thought should be done to achieve the optimal volumes. Their responses determined what ethanol volumes would be required given the existing blend mandate (Malawi Government, 2010). Significantly the respondents did not recognise the blend mandate as a government initiative promoting ethanol use. The blend mandate is at twenty percent (20%) ethanol and eighty percent (80%) petrol (Extra Ordinary Gazette 31st December 2010).
The major finding is that ethanol in the short term is complimentary to fossil fuel and not a replacement. This suggests a preference for a phased increase of ethanol blending. The view of the majority was that the blend mandate should be

fifty percent (50%) to achieve optimal volumes of fuel. Thus the optimal volume of petrol and ethanol is equal in the fuel portfolio. Diesel blending with ethanol is not as well-known and therefore not yet well supported.

6.6.2 Potential contribution of ethanol to the economy.

Against the background that ethanol production and use has been going on for thirty years in Malawi the respondents were asked to indicate what they saw as the potential contribution of ethanol to the economy. The respondents unanimously agreed that the impact on the economy has been muted due to the failure by both the ethanol industry and government to fully harness the benefits of ethanol use to enhance the economy. Respondents also unanimously agreed that ethanol use had huge potential benefits for the Malawi economy including the following (Chapter 4, section 4.6.5):

a) **Forex saving on fuel imports**

Ethanol reduces the volume of fuel that must be imported and thus reduces the requirement for forex which is a saving and benefits the economy.

b) **Freight cost reduction on imports**

The freight cost for the portion of imported fuel taken up by ethanol via blending is a saving that contributes to the economy.

c) **Reduction of fossil fuel dependence**

The bulk of fuel used is fossil. The use of ethanol reduces directly the volume of fossils that are imported thus positively impacting the economy.

d) **Increase energy security**

Risks of supply interruption associated with fuel imports are mitigated by ethanol inclusion in the liquid fuel portfolio directly proportional to the volumes blended.

e) **Further reduction of fuel import costs by importing lower octane fossil fuel**

Importation of lower octane petrol with the intention of boosting the rating using ethanol has never been done in Malawi. If implemented the lower octane petrol imported would represent a cost saving as lower octane petrol is cheaper.

f) **Lower GHGs.**

Ethanol reduces harmful emissions and therefore fewer cardiovascular and lung diseases are seen. This results in a more productive workforce and lower national health costs.

g) Enhanced access to Global Environmental Funds.

If a clear biofuel policy and strategy are adopted the Government can access funds to implement strategies. The NEPAD Climate Change Fund is an example of a fund accessible by government but not the private sector (NEPAD, 2014). This would act as a source of forex, thus contributing positively to the economy.

h) Increased employment opportunities as ethanol production increases.

Small holder farmers and rural communities experience higher incomes as more sugarcane and other energy crops are grown. This in turn benefits the economy.

The research revealed that diesel blending was not well known. However, literature showed that in fact diesel blending with ethanol (diesohol) was successfully tested in Malawi in the 1990s (Chapter 4, section 4.6.6). This is a major potential contribution to the economy which ought to be harnessed.

The findings in Chapter 4 are captured in Table 5.1 (Chapter 5) where various frameworks are compared and the framework in Table 5.2 incorporates the findings. Thus the goal was reached.

6.7 Theoretical and practical contributions to knowledge of the research

This research has made many theoretical and practical contributions to knowledge in this area of study . In the first instance, there has been no research which explored strategically increasing ethanol in the liquid fuels portfolio in the Malawi context, as such this represents a significant contribution to knowledge.

In the following the theoretical and practical contributions to knowledge of the research are highlighted.

The theoretical contributions are presented first followed by the practical contributions.

6.7.1 Contributions to Policy Awareness

One of the important theoretical contributions is that the research raised awareness of the importance of managing the portfolio of liquid fuels. The findings in chapter 4 section 4.2 show that all the respondents agreed there was a distinct absence of awareness. Policies and strategies that are devoted to increasing both the production and use of ethanol should be put in place and regularly revised in light of changes in the sector. The research also raised awareness of the trade-offs that exist between land use for other crops and land use for the production of ethanol chapter 2 section 2.13. Specifically it has made contributions to the understanding that there is need for a conscious policy effort to be made by the government if both the production and use of ethanol is to be sustainably increased.

6.7.2 Contribution to Understanding Frameworks

The research also contributed to the theoretical understanding of the similarities and differences between the different frameworks that were reviewed. As already noted the EU and Brazilian frameworks have as their motif the reduction of GHGs (Chapter 5, Table 5.1; Chapter 2, 2.18). The American framework on the other hand has the twin objectives of reducing oil dependency and reduction of GHGs, the prioritizing between the two depends on the author's emphasis (Chapter 2, section 2.14.2, section 2.18; Tiffany, 2009). The strategic framework developed for Malawi focuses first on economic development as shown by the respondents relevance ranking of the sustainability criteria much like the Indian one (Chapter 4, section 4.1.1).

The Brazilian ethanol framework had its origins in the 1973 OPEC embargo as was the American one which was exacerbated by the Iranian hostage crisis in 1979 (Chapter 2, section 2.16.2). The shift from this stance to GHGs came later. It has been noted that although the production and use of ethanol in Malawi had similar beginnings with Brazil no framework evolved for over thirty years unlike the response of the other countries; for example Brazil developed ProAlcool, the USA had FARM Bills and the EU had the Directives on biofuels (Chapter 2, section 2.18). This strategic framework is therefore significant.

Subsidies for ethanol production and use have been a feature of the Brazilian, American, Chinese and Indian frameworks at various times and are legislated to chart the direction of ethanol production and use by subsidizing energy crops on a large scale (Chapter 5, Table 5.2). This framework differs in that the subsidy is for a food crop, sugarcane, and targets small holder sugarcane farmers.

The Brazilian framework recognizes ethanol as a stand-alone fuel as well as various blends of petrol and ethanol. The Chinese and Indian frameworks recognize blends of ethanol and petrol but not ethanol as a stand-alone fuel. This framework seeks to make ethanol a stand-alone fuel similar to Brazil.

The strategic framework developed in this research is to reside in the National Energy Policy as opposed to the other frameworks which are stand-alone biofuel frameworks or policies. This is in cognizance of the lengthy legislative process as shown by how long it took to return the blend mandate level to twenty percent (20%) from the 2005 ten percent (10%) level (Saka et.al, 2005; Extra Ordinary Gazette 2010).

The frameworks in Brazil and the EU offer incentives to downstream industries such as flexi-vehicle manufacturers. While the American, Indian and Chinese frameworks offer incentives upstream to energy crop farmers and not equipment manufacturers. This strategic framework seeks to incentivize importers of flexi vehicles and other ethanol manufacturing equipment and smallholder sugarcane farmers already mentioned. This is reflective of the absence of a relevant manufacturing sector unlike in the other developed countries and regions.

6.7.3 Contribution to Understanding Sustainability Criteria

A theoretical contribution was the resultant sustainability criteria for Malawi (Chapter 4, section 4.1.1). Significantly, the research revealed that the GHG reduction criterion for Malawi was not primary. This was in contrast to the EU and Brazil where biofuel use is aimed at reducing GHG emissions (Xavier, 2007; European Parliament Council, 2009; Mitchell, 2010).

The positive economic contribution sustainability criterion emerged as the most important for Malawi in this research. MERA had envisaged that ethanol use “will enhance rural livelihoods, welfare and expand income generation opportunities" (MERA, 2008, p.4). This finding finds congruence here and shows the validity of the Indian Biofuels Policy rationale of subsidizing small sugarcane farmers to enhance rural development (Chapter 2, section 2.18.4).

The research investigated seventeen criteria and six were found to be important in the following order: positive economic contribution, air quality improvement (GHG reduction), positive forex effect, energy security improvement, fossil dependence reduction and social welfare impact (Chapter 4, section 4.5.1.1 to 4.5.1.6).

The LUC sustainability criterion in this research had mixed responses showing that it was not well recognized by the respondents. This contrasts with the Brazilian and EU cases where LUC is a largely established sustainability criterion although uniformity regarding what parameter to consider has not yet been achieved (Chapter 4, section 4.5.1.7).

6.7.4 Contribution to literature.

Not much research has been done in Malawi concerning the position of liquid fuels for the energy market in Malawi. Consequently literature on the subject is limited (Chapter 1, section 1.12). This research has, therefore, contributed to the available literature. Specifically, it has contributed to the following understanding:

- That fuel ethanol should be treated as a standalone fuel.
  The respondents concluded that ethanol should be a standalone fuel in Malawi (Chapter 4, section 4.2; 4.4). Biofuel use in the transport sector continues to be linked to fossil fuel (petrol and diesel) inspite of its proven capabilities and advantages as a standalone fuel and the known fact that fossils are depleting and irreplaceable (Chapter 4, section 4.3.2; Grubb, 2011; Umbach, 2010; Hubert, 1956). This research shows that this paradoxical treatment of ethanol fuel is not consistent with its well documented advantages.

- That ethanol fuel pumps should be installed in the major cities of Malawi as an awareness strategy (Chapter 4, section 4.2.3). This implies that ethanol must be recognized as a fuel in its own right as opposed to blending with petrol (fossil fuel).

- That increasing fuel ethanol volumes is a pathway for reducing the dominance of fossils and promoting renewable fuel (Chapter 4, section 4.3.2).
- That ethanol pricing should be independent of the fossil fuel price (Chapter 4, section 4.4.2). This contribution makes it clear that ethanol fuel need not be linked to fossil fuel anymore.
- That ethanol fuel production and use is meant to reduce the dependence on fossil fuels. This aspect featured prominently because of the land lockedness of Malawi as shown by the major fuel disruptions caused by wars in neighbouring countries (Chapter 4, section 4.5.1.8; Robinson, 2009).

A contribution to the biofuels literature in Malawi has been made specifically in that the ambivalent treatment of ethanol fuel eclipses its major advantages. It therefore must be a standalone fuel. Reduction on the dependence on fossil fuel has been shown to be necessary for Malawi by this research both from a historical standpoint and from an energy security viewpoint.

6.8 Practical Contributions

The practical contributions that this research has made are many and varied. They are summarized in the paragraphs that follow.

6.8.1 Framework

A framework has been successfully developed (Chapter 5, Table 5.2). This is the first and most important practical contribution. If used well the framework for Malawi will lead to the increased production and use of ethanol. However, Fiksel et al., (2012, p.6) states that *"many sustainability frameworks have been proposed and used by different organizations around the world. ………. The choice of an appropriate conceptual framework and corresponding indicators is heavily dependent upon an individual's purpose, worldview, and system of values".*

As observed by Hecht (2011) the strategic framework obtained through biofuels sustainability research "will provide better information to decision makers on the tradeoffs and opportunities of increased biofuel production". The practical contribution is that decision makers now have a tool for sustainably increasing ethanol production and use. Furthermore, a biofuels policy evolving directly from this framework can be embedded in the existing National Energy Policy.

6.8.2 Biofuel Production and Use Sustainability Criteria

The practical contribution is that biofuel production and use pathways have been identified and can be assessed for sustainability using these criteria. Benefits accruing from ethanol use in particular and biofuels in general can be quantified.

6.8.3 Advantages of ethanol

The advantages of ethanol are well documented in literature but not all are well implemented or even properly recognized in Malawi. This research has successfully contextualized these advantages for Malawi (Chapter 4 section 4.3.2). For example, ethanol can be used to enhance the octane number of petrol implying that Malawi can import lower octane cheaper petrol and boost it up using ethanol. This is a theoretical contribution. However the realisation of this advantage in practice requires a systemic change in the way Malawi sources fossil fuels, given the landlocked reality.

The practical contribution is that some of these advantages will result in tangible benefits for the country. First is the positive economic contribution of ethanol in the liquid fuels portfolio by directly saving at least twenty percent of forex used for importing fossil fuels given the blend mandate (Malawi Government, 2011). As pointed out by Nkomo (2009, p.20) “price fluctuations result in a flow of foreign exchange resources to oil producers, which would otherwise be used to stimulate the economy”.

The reduction of GHGs is connected to lower incidents of diseases or health conditions such as asthma, pneumonia, cardiovascular ills, and bronchitis (Fischetti, 2011). The practical contribution is that the ministry of health will spend less in treating these conditions and redirect the resources to other important health interventions.

According to this research energy security, the third sustainability criterion, is positively impacted by the inclusion of ethanol in the liquid fuels portfolio. First the total volume of fuel is increased. Secondly the ethanol volume cushions fossil fuel shortages as happened between 2010 and 2012 (Kambatata, 2012).

The finding in Chapter 4, section 4.3.3, on increasing land under sugarcane as a pathway in order to increase ethanol volumes implies employment opportunities. One advantage of ethanol use cited in literature is the positive social impact of creating employment (Jamieson, 2011; Chipukunya and Kacelenga, 2011; Fumo, 2009; Van Zyl, 2007). As already noted this aspect is also a sustainability criterion for ethanol production and use.

The advantages of ethanol discussed in the findings (Chapter 4) have tangible benefits and are practical contributions of this research.

6.9 Limitations of the research

Time constraints did not allow for the interviews at all levels in the liquid fuels industry in general and ethanol industry in particular. Upper echelon strategists were targeted as well some personnel at the operational level. This allowed the espoused strategies to be compared with implementation, thus mitigating the possibility of data incongruence.

The availability of targeted interviewees at the appointed time was not always guaranteed. However, questionnaires were self-administered to the targeted interviewees. Further, the various energy regulatory, Southern Africa Development Community (SADC) sugar producers and engineering conferences of 2013, afforded data validation opportunities. The level of confidence in the data is credible.

The literature on Malawi biofuels is limited. Biofuel discussions at various fora, such as the Ministry of Energy meetings on hydrous ethanol as a fuel and the SADC sugar producers’ conferences, specifically asked the researcher to present on ethanol. The ensuing question and answer sessions provided a valuable opportunity to the understanding of ethanol as a fuel in Malawi.

6.10 Further Research

This section proposes areas of further research. The areas were identified as gaps that could not be adequately addressed by this research calling for further research. The areas are listed in the paragraphs that follow:

6.10.1 LUC in Malawi

The LUC or ILUC discussion in the Malawi ethanol production sustainability context requires further interrogation. Land use change (LUC or ILUC) had no consensus among the interviewees. Consistent with the literature review this aspect was highly debatable (Chapter 2, section 2.4.1). A report by Kasunda (2012) about residents protesting the sale of "their" land in Chikwawa for a sugar plantation underscores this confusion. This is land use change (LUC) from cattle grazing and maize subsistence production to estate food crop (sugar) production and not a food versus fuel debate as in the EU context. Currently the LUC or ILUC discussion has emerged as a non-issue for Malawi in this research. This however presents an area for further research because Malawi ethanol has been sold in the EU in the past, where sustainability declarations include product origin land practices.

6.10.2 Framework solutions

The framework in chapter 5 has a number of solutions suggested, warranting further research for increasing ethanol volumes. Among them are the following:

a) Introducing sweet sorghum as an energy crop to complement sugar cane molasses. Agronomy experts would need to apply previous research or investigate this possibility for the Malawi context.

b) Increasing the area under sugar cane in Malawi is overwhelmingly the preferred pathway to increasing the volume of ethanol in the liquid fuel portfolio. A separate study needs to establish how the sugar cane hectrage can be increased given the now established sustainability criteria.

c) Supporting and encouraging biotechnology research to increase sugar cane yields per hectare and increase the sugar content in sugar cane as a long term solution.

d) Improving ethanol extraction techniques from molasses to raise the ethanol yields from molasses.

e) Investigating other types of ethanol feedstocks such as wood chips and crop residues, commonly known as second and third generation biofuels.

The framework itself may be extended through further study as the liquid fuels particularly ethanol industry in Malawi and globally develops.

6.10.3 Sustainability criteria overlap

The sustainability criteria emanating from this research for ethanol production and use in Malawi include:

a) Making a positive economic contribution
b) Reducing air pollution
c) Having a positive effect on climate change
d) Impacting positively on job creation
e) Enhancing energy security
f) Reducing dependence on imported oil

There is overlap or interrelatedness of some of the criteria. For example energy security and economic contribution are related, as is a positive economic contribution and reduced dependence on imported oil. Therefore further interrogation is recommended so that evaluations of ethanol production and use are not ambiguous.

The following are the recommendations of this research. These proposed actions emanate from the framework.

6.11 Recommendations

1. Biofuels policy to be embedded in the NEP, specifically the following actions must be taken (Chapter 5, Table 5.2):
    a) Make ethanol a stand-alone fuel.
    b) Undertake public awareness campaign for ethanol.
    c) Cap ethanol price not to exceed 65% petrol price.
    d) Include diesel blending with ethanol.
    e) Mandatory strategic ethanol storage reserves for large-scale fuel importers.
    f) Specify energy crops for biofuels & land criteria.
    g) Effluent regulation

2. Government should give incentives. Specifically the following should be done:
    a) Lower the ethanol price for end user benefit.
    b) Change the pricing formula for ethanol and delink the ethanol price from petrol.
    c) Reduce levies on ethanol.
    d) Give input subsidy for small holder sugar cane farmers to increase raw material.
    e) Allow duty free status for ethanol production equipment and spares.
    f) Make a policy to import flexi vehicles for government fleet as government has largest vehicle fleet.
    g) Allow duty free status for conversion kits for older vehicle makes so that end users can switch to ethanol use.

3. Increase feedstock for ethanol production as follows:
    a) Grow more sugarcane as energy crop.
    b) Increase sugarcane yields per hectare.
    c) Develop the use of other crops e.g. sorghum to compliment sugarcane.
    d) Make a policy against use of maize as an energy crop.

4. Implement FFV imports for government fleet.
    a) Government to implement EDVP recommendations as a pace setter for the auto industry.

5. Research energy crop extraction yield increases:
    a) Improve ethanol extraction methods
    b) Reduce effluent volumes to stem ethanol losses to effluent.
    c) Biotech research to increase sugarcane yields per hectare and sugar content in cane.

6.12 Overall conclusion

As noted biofuels literature for Malawi is limited (Chapter 1, section 1.12). During energy and biofuels meetings and conferences locally the researcher and practitioner colleagues were asked to make presentations on ethanol in the period when MERA was being formed. The minutes from these meetings and conferences are part of the literature reviewed. It is not clear whether the researcher's role in these meetings and conferences affected the respondents' answers six or seven years later.

In the course of this research some interviewees changed jobs and were encountered more than once in different roles within the energy sector. One interviewee was in two roles at the same time, a CEO in one organization and a board director in another. The researcher asked slightly varied questions to cope with this reality. All interviewees were available although the timing of the interviews was extended in order to access them. Some interviews were very long due to the researcher being known by the respondents from previous interactions in the energy sector. The research timeline therefore was increased from three years to five. The whole exercise was a positive learning experience in spite of a number of interruptions, changes in second supervisors resulting in long feedback response periods and changes in areas of emphasis during research.

References (Harvard Style)

Abbasi, T. and Abbasi, S. A. (2012) Is the use of renewable energy sources an answer to the problems of global warming and pollution? *Critical Reviews in Environmental Science and Technology*, 42(2) pp. 99-154.
Available from:< http://dx.doi.org/10.1080/10643389.2010.498754 > [Accessed 27 July 2012].

ADB (2010) Crude oil and natural gas production in africa and the global market situation. *Commodities Brief* 1(4). 8 October 2010.
Available from: <
http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Commodity%20Brief%20Oil%20and%20gas%20Final.pdf > [Accessed 20th August 2012]

AFDB (2010) *Annual report 2010*. African Development Bank [Online]. Available from:
<http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Annual%20Report%202010%20EN.pdf> [Accessed 4 April 2016].

African Vault (2015) *African oil producing countries*. Available from:
< https://www.africanvault.com/oil-producing-countries-in-africa/ >
[Accessed 7 Jan 2017].

Ahmad M., Zafar M., Sultana S., Khan M. A., Hasan A., Riaz M. A.
Ahmed S. (2013) Policy recommendation for renewable energy from biofuels, energy sources, part b: *Economics, Planning, and Policy*, 8(1), pp.67-75, DOI: 10.1080/15567249.2011.569832. Available from; <
http://www.tandfonline.com/doi/pdf/10.1080/15567249.2011.569832> [Accessed 7 July 2014].

Agricultural Act (2014) Public Law 113-2642-January 3, 2014. Available from: < https://www.gpo.gov/fdys/pkg/PLAW-110publ246/pdf/PLAW-110publ246.pdf> [Accessed 6 September 201].

Akpalu, W., Arndt, C., Mahrt, K., Kohlin, G., Zikhali, P., Rahim, A., Robinson, E., Weldegebriel Alem, Y., Di Falco, S., Yameogo, N., Ockwell, D., Byrne, R., Vincent, K., Koomson, T., Sperling, F., Urama, K. (2012) -*"Towards Green Growth in Africa" .* African Development Report 2012.
Available from: < http://www.afdb.org/en/knowledge/publications/african-development-report/> [Accessed 1 April 2013].

Allen, R.C. (2012) *Backward into the future:The shift to coal and implications for the next energy transition*. Energy Policy [Online]. Available from: <http://dx.doi.org/10.1016/j.enpol.2012.03.020> [Accessed 1 April 2013].

Almeida, C. (2007) *Sugarcane ethanol: Brazil's biofuel success.* SciDev.Net [online]. Available from: < http://www.scidev.net/global/policy/feature/sugarcane-ethanol-brazils-biofuel-success.html> [Accessed 4 June 2014].

Anh-Thu,N.and West,G. (2004) Advantages and Disadvantages of Using Ethanol: The Consumer Viewpoint. Paper presented at: *AIEA2 International Conference and WORKSHOP of the CAES Laval University Québec*. Available from :< https://www.nmma.org/lib/.../Ethanol_advantages_and_Disadvantages> *[Accessed 30 June 2013].*

Armitage, A. (2007) Mutual Research Designs: Redefining Mixed Methods Research Design. Paper presented at: *the British Educational Research Association Annual Conference, Institute of Education.* University of London, 5-8 September 2007. Available from:< http://www.leeds.ac.uk/educol/documents/167799.htm> [Accessed 23 May 2016].

Balat, M (2008) Global Trends on the Processing of Bio-fuels. *International Journal of Green Energy,* (5)3, pp.212-238. Available from: < http://dx.doi.org/10.1080/15435070802107322> [Accessed 23 January 2012].

Balat, M. (2009) Bioethanol as a vehicular fuel: a critical review. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, (31)14, pp.1242-1255 Available from:< http://dx.doi.org/10.1080/15567030801952334> [Accessed 29 June 2014].

Balat, M. (2011) Production of bioethanol from lignocellulosic materials via the biochemical pathway : A review. *Energy Conversion and Management* (52)2, pp.858–875. Available from: < http://www.sciencedirect.com.ezproxy.bolton.ac.uk/science/article/pii/S0196890410003791> [Accessed 29 June 2014].

Barber, A., Pellow, G., Pereira, M. (2008) The Sustainability of Brazilian Sugarcane Ethanol: A Literature Review. *Energy Efficiency and Conservation Authority (EECA)*, New Zealand, pp.41. Available from : <http://s3.amazonaws.com/zanran_storage/www.eeca.govt.nz/ContentPages/16021933.pdf> [Accessed 10 December 2012]

Barret B.(2008) Peak Oil: What does it mean to you? Paper presented at: *Royal Melbourne Institute of Technology.* Royal Melbourne Institute of Technology, 6 July 2008. Available from: < http://ourworld.unu.edu/en/peak-oil-what-does-it-mean-to-you> [Accessed 24 June 2015].

Bass, B.M. (1983) *Organisational decision-making*. Irwin: Homewood IL.

Batidzirai, B. (2007) Cane Energy for Sustainable Development and Economic Competitiveness in Southern Africa. *Cane Resources Network for Southern Africa (CARENSA* [Online]. Available from: < http://www.carensa.net/PDF/Cane%20Energy%20For%20Sustainable%20Development%20And%20Economic_July07.pdf> [Accessed 24 May 2015].

Batidzirai, B., Johnson, F.X., (2012) Energy security, agro-industrial development and international trade: the case of sugarcane in southern Africa. In: *Gasparatos, A., Stromberg, P. (Eds.), Socio-economic and Environmental Impacts of Biofuels: Evidence from Developing Nations.* Cambridge University Press, London (Chapter 12).

Bernard, H.R. (2000) *Social research methods: qualitative and quantitative approaches.* Thousand Oaks, CA: Sage.

Berg, C. (2013) *Analysis and Outlook Prepared for METI*. F.O. Licht World Fuel Ethanol 2013. Available from: < http://www.meti.go.jp/report/downloadfiles/g30819b40j.pdf> [Accessed 10 November 2015].

Biofuel Association (2012) *Minutes of the 11th Meeting of the Bio Fuel Association*. Crossroads Hotel, Lilongwe, 4 July 2012.

Biofuelindonesia. (2007) Biofuel for our future [Online]. Available from: < http://www.biofuelindonesia.com/origin.html> [Accessed 17 July 2011].

Bourguignon, D. (2015) *EU biofuels policy: dealing with indirect land use change. EU Parliament Briefing.* Brussels. Available from: < http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/545726/EPRS_BRI(2015)545726_REV1_EN.pdf> [Accessed 28 October 2015].

Brieskorn, R. (2011) Policy developments on biofuels. Presented at: *the World Biofuels Markets Conference*. Rotterdam, Netherlands, 22 - 24 March 2011.

Briggs, D., Corvalán, C. and Nurminen, M. (eds). (1996) *Linkage methods for environment and health analysis: general guidelines.* 136. World Health Organization Publications.

Buis, T. (2011) How far we've come in the ethanol industry. *Ethanol Producer Magazine* [Online]. July 2011. Available from: <http://www.ethanolproducer.com/articles/8009/how-far-weundefinedve-come-in-the-ethanol-industry> [Accessed 12 September 2011].

Burrell, G. & Morgan, G. (1979). *Sociological paradigms and organisational Analysis*. Ashgate Publishing Company, Aldershot, England.

Bush, G. (2006) State of the Union address, Jan. 31, 2006. Available from:<http://www.whitehouse.gov/stateoftheunion/2006/> [Accessed 16 December 2012]

Butler, E. (2014) Villagers losing their land to Malawi's sugar growers. *BBC Business News* [Online]. Available from: < http://www.bbc.com/news/business-30499219> [Accessed 24 August 2015].

Calvacanti, C.A. (2011) *The 17th conference of the parties (cop17) to the united nations framework convention on climate change* (UNFCCC) *and the 7th Session of the Meeting of the Parties (CMP7) to the Kyoto Protocol*: Durban, 28 November and 10 December 2011.
Available from <
http://unfccc.int/meetings/durban_nov_2011/meeting/6245.php >
[Accessed 20 August 2012].

CARD (2012) *Proceedings of the National Seminar Transitioning from traditional to modern bioenergy in Malawi.* Centre for Agricultural Research and Development (CARD),Lilongwe,Malawi,[Online] Available from:< http://bit.ly/Malawi-bioenergy> [Accessed 17 August 2016].

Chanje, A.(1999) Comments on the production of ethanol in Malawi, [Technical memorandum]. ETHCO, Dwangwa, Malawi.
(2 November 1999).

Chaudhari, A. (2008) PRAJ Presentation, 1st Annual Biofuels Markets Conference. East Africa, Dar es Salaam, 17-18 Sept, 2008.

Chen, Y. (2013) *Optimal design and operation of energy polygeneration systems*. PhD. Massachusetts Institute of Technology, Massachusetts, USA. Available from: < https://yoric.mit.edu/sites/default/files/documents/ChenThesis.pdf > [Accessed 25 August 2015].

Chevron, (2012) Biofuels: turning trash into treasure. *Chevron.com* [Online] Available from: < https://www.chevron.com/Stories/biofuels> [Accessed 28 October 2012].

Chibwana,C. and Fisher, M. (2011) *The impacts of agricultural input subsidies in Malawi:* MALAWI STRATEGY SUPPORT PROGRAM (MaSSP) Policy Note # 5. Available from: < http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/124970> [Accessed 9 October 2015].

Chibwana, C.; Fisher, M.; Jumbe, C.; Shively, G. (2012) Measuring the Impacts of Malawi's Farm Input Subsidy Program. Paper presented at: *the COMESA/ACTESA/MSU 5th AAMP Policy Symposium.* Kigali, Rwanda, 20-22 April 2012. Available from: < http://fsg.afre.msu.edu/aamp/Kigali%20Conference/Chibwana_Measuring_the_Impacts_of_Malawi%E2%80%99s_Farm_Input_Subsidy.pdf> [Accessed 9 October 2015].

Chinamulungu, O. (2015) Government to include ethanol-driven vehicles on its fleet. *The Nation,* 3 July 2015. Nation Publications Blantyre Malawi

Chinamulungu. O. (2016) Ethanol driven vehicle project stalls. *The Nation*, 25 August 2016. Nation Publications Blantyre Malawi.

Chin-Ho Cho, Yun-Peng Chu, & Hao-Yen Yang. (2011). Oil demand and energy security in asian countries. *The Journal of Energy Markets, 4*(2), 27-VI. Available from:

< http://search.proquest.com/docview/878157139?accountid=9653> [Accessed 15 January 2013].

Chipukunya,I. and Kacelenga, E. (2011) *Project RAMA – India report*. Chikwawa, Malawi, July 2011.

Chirembo, K. (2012) Ethanol blend petrol meets requirements. *The Daily Times*, 4 October.

Chirwa, F. (2015) Quelimane Port much better option for Malawi than unrealistic Nsanje Inland Port. *Nyasa Times* [Online]. [Accessed 6 August 2015] Available from:
< http://www.nyasatimes.com/2015/06/01/quelimane-port-much-better-option-for-malawi-than-unrealistic-nsanje-inland-port/>

Chittock, A. (2012) Grand Opening of BERL's Bio Fuel Processing Facility. [Letter] Personal communication (12 September 2012).

Chua, W.F. (1986). Radical developments in accounting thought. *The Accounting Review* (61), pp.601-632.

Coal explorer (2012) *Report - august 07, 2012*. Mumbai, India, Mumbai: Petrosil Group. Available from:
<http://search.proquest.com/docview/1034724418?accountid=9653> [Accessed 1 April 2013].

Colares, J.F. (2008) A brief history of Brazilian biofuels legislation. Case Western Reserve University School of Law. June 25, 2008. *Syracuse Journal of Law & Commerce,* (35)2. Available from: < http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1079994> [Accessed 13 October 2015].

Collis, J. (2003) *Business research*. [Online]. Palgrave Macmillan. Available from: <http://lib.myilibrary.com/ProductDetail.aspx?id=25100> [Accessed 19 August 2014].

Collis.J, and Hussey,R. (2003) *Business research.* [Online]. 2nd ed, Palgrave Macmillan. Available from:<http://lib.myilibrary.com?ID=25100> [Accessed 28 August 2011].

Cooper, D. R. and Schindler, P.S. (2008) *Business research methods*, 10th ed. Boston, MA and Burr Ridge, IL: McGraw-Hill

Cornland, D., Johnson, F.X., Yamba, F.D., Chidumayo, E., Morales, M., Kalumiana, O., Mtonga-Chidumayo, S., (2001) *Sugarcane resources for sustainable development: a case study in Luena, Zambia*. Stockholm Environment Institute, Stockholm,ISBN: 91-88714-71-3.

Corro, G. and Ayala, E. (2008) *Bioethanol and diesel/bioethanol blends emissions abatement.* Laboratorio de Catalisis Ambiental, Instituto de Ciencias, Benemerita Universidad Autonoma de Puebla, 4 Sur 104, Puebla 70000, Mexico. Available from: < http://www.sciencedirect.com/science/article/pii/S0016236108002810 > [Accessed 29 July 2012].

Corvalán, C. F., T. Kjellström, and K. R. Smith. 1999. Health, environment and sustainable development: identifying links and indicators to promote action. *Epidemiology* 10(5), pp.656-660.

Cressy, N, (2012) Next generation bio-fools. *World Biofuels Markets News* [Online] 25 October 2012. Available from:< http://worldbiofuelsmarkets.info/?p=1883> [Accessed 27 October 2012].

Creswell, J.W. (2009) *Research design: Qualitative, quantitative, and mixed methods approaches*. 3rd ed. Thousand Oaks, CA: Sage.
Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. Thousand Oaks, CA: Sage.

Creswell, J. W. (1995), *Research design: Qualitative and quantitative approaches.* Thousand Oaks, CA: Sage.

Crooks, E. (2013) Peak oil. *Financial Times* [Online]. [Accessed 6 January 2013] Available from: <http://lexicon.ft.com/Term?term=peak-oil> .

Crooks, E. (2009) Back to petroleum. *Financial Times* [Online]. 8 July. [Accessed 16 January 2013] Available from <http://search.proquest.com/docview/250217273?accountid=9653>.

Crooks, E. (2009). Wind of change in corridors of power. *Financial Times* [Online]. 5 November. [Accessed 16 January 2013]. Available from <http://search.proquest.com/docview/250251638?accountid=9653>

Curtis, B (2010) U.S.biofuels industry: mind the gap. *Concentric Energies & Resource Group, Inc.* Los Gatos, CA. Available from: <www.ConcentricEnergies.com> [Accessed 4 September 2016].

Daly, H. E. (1973) *Toward a steady-state economy*. W. H. Freeman, San Francisco, CA, USA.

Darvill, A. (2012) Energy resources. [Online]. Available from: <http://www.darvill.clara.net/altenerg/index.htm> [Accessed 4 October 2012].

David, F.R. (2001) *Strategic management*. Upper Saddle River, New Jersey 8th ed. Prentice Hall.

Davies, R. (2013) Mozambique floods, 2000. Available from:< http://floodlist.com/africa/mozambique-floods-2000> [Accessed 8 March 2017].

Davis, G., Mackay, R., MacRae, M., Nicolson, L., Currie, C., MacPherson, R., Banda, E., Tembo, K., Ault, G., Frame, D., Picken, S. (2011) *Supporting Community Energy Development in Malawi.* A scoping study for the Scottish Government. Available from: < www.scotland.gov.uk/Resource/Doc/107396/0122148.docx> [Accessed 28 November 2013].

DELOITTE (2006) *PressCane Limited Audited Accounts 2006.*

DELOITTE (2007) *PressCane Limited Audited Accounts* 2007.

DELOITTE (2008) *PressCane Limited Audited Accounts* 2008.

DELOITTE (2009) *PressCane Limited Audited Accounts* 2009.

DELOITTE (2010) *PressCane Limited Audited Accounts* 2010.

DELOITTE (2011) *PressCane Limited Audited Accounts* 2011.

Demirbas, A. (2010) Progress and recent trends in biodiesel fuels. *Science Direct.* Available from:< http://www.sciencedirect.com/science/article/pii/S0196890408003294 > [Accessed 15 February 2013].

Demirbas, T and Demirbas, A. H. (2010) Bioenergy, green energy. biomass and biofuels. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* [online]. (32)12, pp.1067-1075. Available from: < http://www.tandfonline.com/doi/abs/10.1080/15567030903058600#.Uuqi9GyIpMw> [Accessed 14 February 2013].

Demirbas, A. (2007) Progress and recent trends in biofuels. *Progress in Energy and Combustion Science* (33), pp. 1–18. Available from:< http://observatorioambiental.iff.edu.br/publicacoes/publicacoes-cientificas/biomassa_recente.pdf> [Accessed 1 July 2014]

Demirbas, A. (2005a) Bioethanol from cellulosic materials: a renewable motor fuel from biomass. *Energy Sources* (27), pp.327–337. Available from: < http://www.tandfonline.com/doi/pdf/10.1080/00908310390266643> [Accessed 7 July 2014].

Demirbas, A. (2005b) Hydrogen and boron as recent alternative motor fuels. *Energy Sources* (27), pp.741–748. Available from: <http://www.tandfonline.com/doi/pdf/10.1080/00908310490450836> [Accessed 7 July 2014].

Demirbas, A. (2006) Sustainable biomass production. *Energy Sources, Part A* (28), pp.955–964. Available from: < http://www.tandfonline.com/doi/pdf/10.1080/00908310600718866> [Accessed 7 July 2014]

Demirbas, M.F. and Balat, M. (2006) Recent advances on the production and utilization trends of bio-fuels: A global perspective. *Energy Conversion and Management* , (47), pp. 2371–2381. [online]. Available from:< http://www.sciencedirect.com> [Accessed 8 January 2012].

Demirbas A. (2008) Present and Future Transportation Fuels. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, (30)16, pp.1473-1483 **<** http://www.tandfonline.com/doi/pdf/10.1080/15567030701258519> [Accessed 7 July 2014].

Denzin, N.K. & Lincoln, Y.S. (2000). *Handbook of qualitative research*, 2nd ed, Sage Publications, Thousand Oaks, CA.

De Oliveria, M. E. D., Vaughan, B. E., and Rykiel Jr., E. J. (2005) Ethanol as fuel: energy, carbon dioxide balances, and ecological footprint. *BioScience,* (55), pp.593–602.

Department of Energy Affairs (2003) *National energy policy*. Department of Energy Affairs, Malawi.

Detchon, R. (2007) *Case for ethanol*. Available from: < http://www.energyfuturecoalition.org/biofuels/overview.htm> [Accessed 3 March 2013].

Dictionary.com (2015) Meanings and definitions of words at dictionary.com. [online]. Available from:< http://www.dictionary.com/> [Accessed 8 March 2015].

DOE (2014) *Strategic plan of the department of energy for 2014-2018*. United States Department of Energy 2014. Available from: < http://energy.gov/sites/prod/files/2014/04/f14/2014_dept_energy_strategic_plan.pdf > [Accessed 3 August 2016].

DOE (2015) *World Crude oil price and associated events 1970 – 2014. Office of energy effciecncy & renewable energy*. US Department of Energy.

Available from:<http://energy.gov/eere/vehicles/fact-859-february-9-2015-excess-supply-most-recent-event-affect-crude-oil-prices> [Accessed 6 September 2016].

Drucker, P.F. (1997) *Managing for results***.** Butterworth:Heinamann.

Dufey, A. (2006). *Biofuels production, trade and sustainable development: emerging issues*. International Institute for Environment and Development (IIET), London.

Dyer, J.C., Stringer, L.C. and Dougill, A.J. (2012) Jatropha curcas: Sowing local seeds of success in Malawi? In response to Achten et al. (2010). Paper presented at: *University of Leeds*. Available from: < http://homepages.see.leeds.ac.uk/~lecajd/papers/Dyeretal2012.pdf> [Accessed 3 September 2015].

Dunmore, C. (2011) Biodiesel industry rejects EU land use impact study. Available from:<http://www.reuters.com/article/2011/10/07/us-eu-biodiesel-idUSTRE79650W20111007> [Accessed 13 October 2011].

Dyner, I. (2000) Energy modeling platforms for policy and strategy support. *Journal of the Operational Research Society*. (51), pp.136 – 144.

Easterby-Smith, M., Thorpe, R., Lowe, A. (1991) *Management research: an introduction*. London: Sage.

EBB (2006) EBB comments to the commission consultation on the revision of the EU biofuels directive. [online]. Available from: < http://www.ebb-eu.org/EBBpressreleases/EBB%20answers%20to%20CM%20questionnaire.pdf> [Accessed 1 October 2015].

EISA (2007) U.S. Congress. Energy independence and security act of 2007.

Ellis, F., Kutengule, M., Nyasulu, A., 2003. Livelihoods and rural poverty reduction in Malawi. World Development (31), pp.1495 -1510.

Environmental Affairs Department (2002) Initial National Communication of Malawi. Available from: < http://unfccc.int/resource/docs/natc/mwinc1.pdf > [Accessed 15 October 2015].

EPA (2005) US Congress. Energy Policy Act of 2005. Available from: <www.epa.gov/OUST/fedlaws/publ_109-058.pdf.p 109-58> [Accessed 4 September 2016].

Er, A.C. (2011) A oomparative analysis of the Brazilian bioethanol sector and the Malaysian palm biofuel sector. *Asian Social Science (7)2, pp. 1911-2017* [online]. Available from:< http://ccsenet.org/journal/index.php/ass/issue/view/309> [Accessed 12 September 2011].

ESCOM (2013) REEEP Policy Database. *Reegle* [online]. Available from:< http://www.reegle.info/policy-and-regulatory-overviews/MW> [Accessed 10 February 2013].

Ethanol Driven Vehicle Project (EDVP) (2011) *Assessment of the use of ethanol an an alternative vehicle fuel to petrol in Malawi*. Lilongwe, Malawi.

Ethanolhistory.com (2010 - 2011) Ethanol history - from alcohol to car fuel. *2010-2011 Ethanol history* [online]. Available from: < http://www.ethanolhistory.com/> [Accessed 25 April 2016].

ETHCO (1983 – 2011) *Board Packs*.

European Parliament, Council (2009) Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance). Available from: < http://eur-ex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0028:EN:NOT> [Accessed 9 Nov 2012].

Eurostat (2012) *Transport energy consumption and emissions - Statistics explained.* Available from: <epp.eurostat.ec.europa.eu/statistics> [Accessed 20 November 2012].

Extra Ordinary Gazette 31st December 2010, Malawi Government Press. Available from: <http://www2.epa.gov/sites/production/files/2014-10/documents/framework-for-sustainability-indicators-at-epa.pdf > [Accessed 20 November 2012].

Fiksel, J.; Eason, T.; Frederickson, H. (2012) *A framework for sustainability indicators at EPA .* National Risk Management Research Laboratory Office of Research and Development U.S. Environmental Protection Agency. Available from: < https://www.epa.gov/sites/production/files/2014-10/documents/framework-for-sustainability-indicators-at-epa.pdf > [Accessed 23 May 2016].

Fitzgerald, B. & Howcroft, D. (1998). Towards dissolution of the is research debate: from polarization to polarity, *Journal of Information Technology*, (13) 4, pp.313-326.

Food Conservation and Energy Act (2008) Public Law 110-246-June 18, 2008. Available from: < https://www.gpo.gov/fdys/pkg/PLAW-110publ246/pdf/PLAW-110publ246.pdf> [Accessed 6 September 201].

Fuel Import Statistics 2009, PIL.

Fumo, E.L.D. (2009) *Mozambican criteria for sustainable ethanol production: identification, assessment and stakeholders support*. MSc Thesis Wageningen University. Available from: < https://www.wageningenur.nl/upload_mm/e/e/6/036bd199-8a5f-483a-918f-67df9ffd826f_*MScThesisSustcriteriabioethanolMozambique.*pdf > [Accessed 10 February 2013].

Garnier, J. (2012) Renewable energy coming of age. *Journal of the International Energy Agency (2)*. Avaialble from:< www.iea.org> [Accessed 5 June 2013].

Ghazvinian, J. (2007) *Untapped: the scramble for africa's oil*. Harcourt Inc. Available from: < http://faculty.fairfield.edu/winston/John%20Ghazvinian.pdf > [Accessed 27 August 2015].

Gnansounou, E., et al. (2008) Accounting for indirect land-use changes in ghg balances of biofuels: review of current approaches. *Working Paper,* 437.101. Swiss Federal Institute of Technology of Lausanne, Laboratory of Energy Systems(LASEN).

Goes, T.; Marra, R.; de Araújo, M.; Alves, E.; de Souza, M.O. (2011) Sugarcane in Brazil Current technologic stage and perspectives. *Politca Agricola (XX)1 – Jan./Fev./Mar. 2011*. Available from: < http://ainfo.cnptia.embrapa.br/digital/bitstream/item/80803/1/Sugarcane-in-Brazil-currente-technologic-stage-f.pdf> [Accessed 23 September 2015].

Goodman, C. (2004) The public interest in a 21st century global economy. *Energy Markets 9. 3 (Mar 2004): 37*. Available from: <http://search.proquest.com/docview/228753007?accountid=9653> [Accessed 16 December 2012].

GoM, (2009) *Biomass Energy Strategy for Malawi*. Government of Malawi, Lilongwe.

Gondwe, G. (2014) World bank tears into fisp. *The Sunday Times*, 23 November 2014.

Gonsalves, J..B. (2006) *An asessment of the biofuels industry in India.* UNCTAD, UN. Available from: < http://www.biotechnologie.init-ag.de/BIO/Redaktion/PDF/de/laenderfokus/indien-biofuel-unctad,property=pdf,bereich=bio,sprache=de,rwb=true.pdf > [Accessed 18 November 2012].

Goshu, B.N. and Chopra, P.K. (2003) *A dictionary of research methods*. Leeds, UK: Wisdom House Publications.

Government of India (2002) The gazette of india: extraordinary [part i- sec. I] ministry of petroleum and natural gas. [online]. *Resolution*. No. P-45018/28/2000-C. C. New Delhi, 3 September, 2002.
Available from: < http://www.ethanolindia.net/ethanol_govt.html > [Accessed 19 October 2015].

Government of Malawi (2009) *Biomass Energy Strategy for Malawi*. Government of Malawi, Lilongwe.

Government of Malawi (2011) *Government of Malawi Greenbelt initiative***.** Malawi Government.

Gray, D. (2004), "*Doing research in the real world*". SAGE: London.

Gregory, A.J. (2007) A systems approach to strategic management . Paper presented at: *University of Hull*, Hull UK. Available from: < http://journals.isss.org/index.php/proceedings51st/article/viewFile/840/207> [Accessed 16 May 2011].

Groom, M.J. (2008) Conservation biology; scientists at university of washington describe research in conservation biology. *Energy & Ecology Business,* 2008. Available from: < http://search.proquest.com/docview/201602530?accountid=9653 > [Accessed 14 February 2013].

Grubb, A. (2011) Peak oil primer. *Energy Bulletin* [Online]. Available from:< http://www.energybulletin.net/primer.php> [Accessed 16 May 2011].

Guba, E. (1990) *The alternative paradigm dialog in E.G.Guba (ed), the paradigm dialog.* Sage publications, Thousand Oaks, CA.

Guba, E.G. and Lincoln, Y.S. (1994) *Competing paradigms in qualitative research, in N.K.Denzin and Y.S. Lincoln (eds), Handbook of Qualitative Research*. Sage publications, Thousand Oaks: CA.
Gummesson, E. (1991) *Qualitative methods in management research*, Newbury Park: Sage.

Hair. J , Money. A, Page. M , and Samouel . P, (2007) "*Research method for business*", John Wiley &Sons, ltd.

Hall, J., Matos, S., Severino, L., Beltrão, N., (2009) Brazilian biofuels and social exclusion: established and concentrated ethanol versus emerging and dispersed biodiesel. *J. Cleaner Prod*.(17)1, pp. S77–S85.

Hambrick, D.C. and Snow, C.C. (1977) A conceptual model of strategic decision-making in organizations. *Academey Of Management Proceedings.* August 1977 pp. 109-112 . doi: 10.5465/AMBPP.1977.4977040. Available from:< http://proceedings.aom.org/content/1977/1/109.full.pdf+html> [Accessed 28 December 2013].

Harrison, E.F. (1996) A process perspective on strategic decision-making**.** *Management Decision*, 34 (1), pp.46-53.

Hecht, A. (2011) *EPA's Role: Biofuel Primer on Authorities, Responsibilities, and Research.* [online]. Available from: < http://www.EPA.gov/sustainability > [Accessed 7 September 2015].

Heisey, P.W., Smale, M. (1995) *Maize Technology in Malawi: A Green Revolution in the Making? Research Report No. 4* Cimmyt, Mexico. Janeemo, 2007. Avaialble from: <www.janeemo.org> [Accessed 7 September 2015].

Herrera, M.C. (1997) *Cane, Sugar and the Environment.* FAO Corporate Document Repository. Available from: < http://www.fao.org/DOCREP/005/X4988E/x4988e01.htm> [Accessed 7 June 2012].

Hill, C.W. (2003) *International Business: Competing in the global market place***.** 4th ed. New York, NY: McGraw-Hill Irwin.

Hira, A. (2010) Sugar rush: prospects for a global ethanol market. *Energy Policy,* 39 (11), pp.6925–6935. Available from: < http://dx.doi.org/10.1016/j.enpol.2010.05.035> [Accessed 22 October 2015].

Hira, A. and de Oliveira, L.G.(2009) No substitute for oil? How Brazil developed its ethanol industry. *Energy Policy,* 37 (6), pp.2450–2456. Available from: < http://www.sciencedirect.com/science/article/pii/S0301421510004064#bib30> [Accessed 14 October 2014].

Hoekman,S.K. (2009) Biofuels in the U.S. – Challenges and opportunities. *Renewable Energy,* (34)1, pp. 14-22. Available from: <http://dx.doi.org/10.1016/j.renene 2008.04.030> [Accessed 8 September 2016].

Hopkins, T.K. (1964) T*he exercise of influence in small groups.* Totowa, NJ: Bedmister.

Hubbert, M.K. (1956) Nuclear energy and the fossil fuels. Drilling and production practice. *American Petroleum Institute 1956. Houston Texas.* Available from: <http://www.hubbertpeak.com/hubbert/1956/1956.pdf> [Accessed 6 January 2013].

Hunt, S.D. (1994). On the rhetoric of qualitative methods: towards historically informed argumentation in management inquiry. *Journal of Management Inquiry*, September, pp. 221 – 234.

Hussey, J. & Hussey, R. (1997). *Business research.* Macmillan Press Ltd, Basingstoke.

Hwang, M.J., Yang, C.W., Huang, B.N. (2010) Oil price formation through unstable, inelastic demand and cartel imperatives. *The Journal of Energy Markets* [online]. *(3)4, pp.* 65–85. Available from: < http://www.risk.net/digital_assets/4603/jem_v3n4a3.pdf> [Accessed 17 December 2012].

Institution of Mechanical Engineers (2015) Types of fossil energy. *Institution of Mechanical Engineers*. Available from: <http://www.imeche.org/knowledge/themes/energy/energy-supply/fossil-energy/types-of-fossil-energy> [Accessed 7 September 2015].

International Energy Agency (IEA) (2013) Coal. *World Energy Outlook*. Available from: <http://www.iea.org/topics/coal/> [Accessed 1 April 2013].

Illovo Sugar (Malawi) Limited (2013) *Annual report 2013*. Illovo, Malawi. Available from: <http://www.illovosugar.co.za/About_Us/grouplistedsubsidiaries/IllovoSugar_Malawi_Limited.aspx> Accessed [28th April 2014].

IEA (International Energy Agency) (2017) Total primary energy supply by fuel 2015. *IEA. WORLD ENERGY BALANCES: OVERVIEW (2017 edition)*. [online]. Available from:< http://wds.iea.org/WDS/tableviewer/document.aspx?FileId=1574> [Accessed 7 Jan 2017].

Jackson Michel C. (2011) *Systems thinking: creative holism to managers.* England, John Wiley and Sons Ltd.

Jennings,D. and Wattam, S. (1998) *Decision-making: an integral approach*. 2nd ed.,London: Pitman Publishing.

Jamieson, C. (2011) The Biofuel Sustainability Debate: Getting the message across. Presented at: *World Biofuels Markets Conference*. Rotterdam, Netherlands 22 - 24 March 2011.

Jassi, K. (2015) Malawi to feel anti-smoking lobbies. *Daily Times*. [Online] 23 July. Available from: < http://www.times.mw/malawi-to-feel-impact-of-anti-smoking-lobbies/> [Accessed 1 October 2015].

Jick, T. D. (1979) Mixing qualitative and quantitative methods: Triangulation in action.*Administrative Science Quarterly*, (24) December, pp. 602–611.

Jimu, C. (2015) Illovo invests K25m in winter cropping. *THE NATION*, 13 October.

Johnson, F.X. and Silveira, S. (2014) Pioneer countries in the transition to alternative transport fuels: Comparison of ethanol programmes and policies in Brazil, Malawi and Sweden. *Environmental Innovation and Societal Transitions.* [Online]*. (11), pp.1–24.*. Available from: < http://dx.doi.org/10.1016/j.eist.2013.08.001> [Accessed 25 October 2015].

Jooste, B.(2010) Baby born in tree now a 10-year-old girl. *News/South-Africa* [online]. Available from: < http://www.iol.co.za/news/south-africa/baby-born-in-tree-now-a-10-year-old-girl-1.482858> [Accessed 26 January 2016].

Jumbe, C. Msiska, F., Mhango, L. (2007) *Compete (INCO-CT-2006-032448) First Periodic Activity Report – Annex 6 – 1*. Report on National Policies and Strategies. Available from: < http://www.compete-bioafrica.net/policy/Report_on_National_Policies_and_Strategies.pdf> [Accessed 16th May 2011].

Kaberuka, D (2013) Address by the African Development Bank Group President, at the 50th anniversary of the African Union, Addis Ababa, Ethiopia (25/05/2013). Available from: http://www.polity.org.za/article/afdb-donald-kaberuka-address-by-the-african-development-bank-group-president-at-the-50th-anniversary-of-the-african-union-addis-ababa-ethiopia-25052013-2013-05-25 > [Accessed 4 April 2015].

Kacelenga, E. (2010) THE MALAWI ETHANOL INDUSTRY: 28 Years ON. Presented at: *the Bioenergy Markets Conference*. Maputo 2010.

Kacelenga, E. (2013) Towards an optimal product portfolio of liquid fuels for the malawi energy market: a study to develop a strategic framework for a biofuel producer. Paper presented at: *Malawi Institute of Management.* Lilongwe. June 2013.

Kambatata, W. (2012) Why Malawi needs to explore oil in the lake. *THE DAILY TIMES*, 11 September.

Kandadi, K .R. (2006), *Knowledge management in distributed organisations: developing a meta-level framework.* Ph.D. University of Bolton. Available from: < http://elearning.bolton.ac.uk/file.php/5002/Thesis_1_.pdf> [Accessed 14 August 2014].

Kasunda, A. (2012) CK residents protest land sale. *THE NATION*, 2 October.

Kerzner, H. (2009) *Project management: a systems approach to planning, scheduling, and controlling.* 10th ed. Hoboken, New Jersey: John Wiley and Sons.

Khan, R.A., Khan, A.N., Ahmed, M., Khan, M.R., Shah, Azam, N., Sadullah, F., Dian, F., Ullah, S. & Khan, N. (2012) "Bioethanol sources in Pakistan: A renewable energy resource". *African Journal of Biotechnology,* (10)86, pp. 19850-19854.

Khanje, T. (2012) Fuel reserves are crucial for Malawi. *THE DAILY TIMES*, 10 September.

Khanje , T (2012) 'Malawi should have fuel reserves'. *Daily Times.* [online]. Available from <http://www.bnltimes.com/index.php/daily-times/headlines/business/11490-malawi-should-have-fuel-reserves> [Accessed 14 May 2013].

Khazanchi, D. and Munkvold, B.E. (2003) "On the Rhetoric and Relevance of IS Research Paradigms: A Conceptual Framework and Some Propositions". *Proceedings of the 36th Hawaii International Conference on System Sciences (HICSS' 03).* Big Island, HI, USA. 6-9 January 6 – 9.

Khunga, S. (2015) No prices set for Zambia maize. *THE NATION*, 7 September.

Kincheloe, J.L. & McLaren, P.L. (1994). *Rethinking critical theory and qualitative research*. In: Denzin, N.K. and Lincoln, Y.S., (Eds.) *Handbook of Qualitative Research*, London: Sage.

Kitman, J. (2000). "The Secret History of Lead". *The Nation.* [Online]. 2 March. Available from:< http://www.thenation.com/article/secret-history-lead?page=full> [Accessed 28 October 2012].

Kjellström, T. and C. Corvalán. 1995. Framework for the development of environmental health indicators. *World Health Statistics Quarterly,* 48(2), pp.144-154.

Klein, H.and Myers, M. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly*, 23(1), pp.67-94.

Koplow, D. (2007) “Biofuels—at what cost? government support for ethanol and biodiesel in the united states: 2007 update.” Prepared for: *the Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD), October.* Available from: < www.globalsubsidies.org/files/assets/Brochure_-_US_Update.pdf.> [Accessed 4 September 2016].

Kuhn, T.S. (1970) *The structure of scientific revolutions*. Second Edition, Enlarged Volume II (2). Available from: <http://projektintegracija.pravo.hr/_download/repository/Kuhn_Structure_of_Scientific_Revolutions.pdf> [Accessed 14 August 2014].

Lamers, P.; Hamelinck, C.; Junginger, M.; Faaij, A. (2011) International bioenergy trade—a review of past developments in the liquid biofuel market. *Renewable Sustainable Energy Reviews*. (15), pp. 2655–2676. Avaialble from: < http://dx.doi.org/10.1016/j.rser.2011.01.022> [Accessed 14 October 2016].

Landell, M. G. A. L.; Pinto, L. R.; Creste, S.;Chabregas, S. M.; Burnquist, W. L. (2010) *Roadmap tecnológico para etanol: componente melhoramento genético biotecnologia.* In: CORTEZ, L. A. B. (Org.). *Bioetanol de Cana-de-açúcar P&D para produtividade e sustentabilidade*. São Paulo: Blucher, 2010. p. 883-885.

Lane, J. (2011) Bio energy resources of Malawi planning $18m jatropha biodiesel plant**.** *Biofuels Digest* 2011. Available from: <http://biofuelsdigest.com/bdigest/2011/05/20/bio-energy-resources> [Accessed 20 July 2011].

Langevin, M. (2010) Brazil's big oil play: how this nation is charting national energy security. *Centro Universitário de Brasília (UniCEUB).*

Larsson, J. (2006) *A Cost benefit analysis of ethanol production from cereals in Sweden- A case study approach*. MSc. Swedish University of Agricultural Sciences . Available from: < https://stud.epsilon.slu.se/10861/1/larsson_j_170925.pdf> [Accessed 14 May 2013].

Lea, N. and Hanmer, L (2009) *Constraints to Growth in Malawi*. *The World Bank Africa Region Southern Africa Poverty Reduction and Economic Management Unit October 2009*. World Bank . Available from: < https://openknowledge.worldbank.org/bitstream/handle/10986/4289/WPS5097.pdf?sequence=1> [Accessed 14 May 2013].

Lee TH, Ball Jr. BC and Tabors RD (1990) *Energy aftermath, how can we learn from the blunders of the past to create a hopeful energy future*. Harvard Business School Press. Boston, Massachusetts.

Lendle, A. and Schaus, M. (2010) *Sustainability Criteria in the EU Renewable Energy Directive:Consistent with WTORules?* ICTSD information note No. 2. Available from: <http://www.ictsd.org/downloads/2011/12/sustainability-criteria-in-the-eu-renewable-energy-directive-consistent-with-wto-rules.pdf> [Accessed 19 July 2015].

Linn, F. (2014) 1,000,000 Strong Against Offshore Drilling.[online]. Available from: <https://www.facebook.com/dontdrill/posts/844349672262714> [Accessed 25 April 2016].

Loon, M. (2010) Driving innovation across the LNG value chain. *World Petroleum Council: Official Publication 2010.* [online]. Available from: < http://www.world-petroleum.org/resources/special-publications/231-yearbook> [Accessed 11 April 2016].

Loppacher, L.J. and Kerr, W.A. (2005) Can biofuels become a global industry?: Government policies and trade constraints. *Energy Politics*. (5), pp. 7–27. Available from: < http://www.tandfonline.com/doi/full/10.1080/15435070802107322 > [Accessed 14 October 2011].

Löfvenberg, U. (2007) *Short report from the Swedish experience of using low blend of ethanol derivative in diesel, EDdiesel*. SEKAB BioFuels & Chemicals AB. Available from: <www.sekab.com> [Accessed 14 October 2011].

Low, S.A. and Isserman, A.M. (2009) Ethanol and the local economy**.** *Economic Development Quarterly*. 23 (1). Available from:< http://www.farmdoc.illinois.edu/policy/research_reports/ethanol_report/Ethanol%20Report.pdf#page=65> [Accessed 15 May 2011].

Lyford, C.P., Ricks, D.J., Peterson, C., Sterns, J.A. (2002) A framework for effective industry strategic planning. *Journal of Agribusiness*. 20 (2).

Lysons, K. and Farringdom (2003). *Purchasing and supply chain management.* 5th Edition, Harlow and Pearson Education.

Maanen, V (1983) *Quantitative methodology*. Sage: London.

Malawi Development Growth Strategy (2006 – 2011). Available from: <http://www.malawi-invest.net/docs/Downloads/Malawi > [Accessed 15 May 2011].

Malawi Government (2010) Extra Ordinary Gazette, 31st December, 2010.

Malawi National Energy Policy (2003).

Malikwa, M. (2016) AfDB gives Malawi K 12bn for food aid. *THE NATION*. 17 November. p. 4.

Masina, L. (2014) Malawi Court Blocks Move to Scrap Election. VOA News. [online]. Available from: < http://www.voanews.com/content/malawi-president-annuls-election-orders-fresh-vote-in-90-days/1921639.html> [Accessed 13 August 2015].

McGrath, M. (2013) 'Land grab' database reveals hype. BBC News. [online]. Available from: < http://www.bbc.co.uk/news/science-environment-22839149 > [Accessed 12 June 2013].

McGrath, M. (2015) Climate change: Obama unveils Clean Power Plan. BBC News. [online]. Available from: http://www.bbc.com/news/world-us-canada-33753067> [Accessed 6 August 2015].

Meher, L.C., Sagar, D.V., Naik, S.N. (2006). Technical aspects of biodiesel production by transesterification—a review. *Renewable and Sustainable Energy Reviews* (10), pp.248–268.

Meadows, D. (1998) *Indicators and Information Systems for Sustainable Development.* The Sustainability Institute, Hartland VT, USA. http://www.sustainer.org/pubs/Indicators&Information.pdf.

MERA (2008) MERA Strategic Plan. MERA stakeholder consultative workshops 28th – 29th April 2008 and 25th to 26th May 2008; Mangochi.

MERA (2011) Price Build up. Malawi Energy Regulatory Authority.

MERA (2013) Price Build up. Malawi Energy Regulatory Authority.

Merriam-Webster (2014) *Unabridged Merriam-webster dictionary*.[online] Merriam-Webster dictionary. Available from; <http://www.merriam-webster.com/dictionary/ontology > [Accessed 18 Augsut 2014].

Mintzberg , H. Raisinghani, D. and The'ore't, A. (1976) The structure of "unstructured" decision processes**.** *Administrative Science Quarterly*. (21), pp. 246-275.

Mintzberg, H., Ahlstrand, B., Lampel, J. (1998) *Strategy safari: the complete guide through the wilds of strategic management.* London: FT Prentice Hall.

Mitchell,D.(2010*) Biofuels in Africa: Opportunities, Prospects, and Challenges*. World Bank Report. Available from < http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8516-6 > [Accessed 10 February 2013].

Mkhomaanthu, B. (2013) *Minutes Of The Meeting Held On 18th June 2013 At PressCane Limited Boardroom With Shire Valley Cane Growers Trust.* Press Chikwawa.

Mndolo, F. (2013) *Minutes Of The Meeting Held On 15th May 2013 At PressCane Limited Boardroom With Shire Valley Cane Growers Trust.* Chikwawa.

Moran, D. (2002) *Introduction to phenomenology*. [online]. New York, NY. Routledge. Available from: < http://web.ebscohost.com/ehost/ebookviewer/ebook/bmxlYmtfXzcwODA5X19BTg2?sid=4ef080c4-96e8-4b93-83ce-638c71fe614b@sessionmgr112&vid=3&format=EB&rid=1> [Accessed 5 January 2014].

Nalivata, P.C., and Mapemba L.D. (2012) Impact of Biofuels on Food Crops and Livestock Production in Malawi. *Proceedings of the National Seminar on Bioenergy*. Bunda College, University of Malawi, Lilongwe. 2 October 2012.

Namangale, F. (2012) Oil companies have enough fuel reserves – Faulkner*. THE NATION. 12* September.

National Bank of Malawi (2014) *Foreign exchange rates*. Available from: < http://www.natbank.co.mw/index.php/2013-01-10-09-18-18/foreign-exchange-rates-nbm> [Accessed 27 April 2014].

National Statistics Office: Malawi (2013) *Trade statistics brief release Year End 2012*. Available from: <http://www.nso.malawi.net/ > [Accessed 6 October 2011].

NCST (2011) *ETHANOL DRIVEN VEHICLE PROJECT REPORT*. National Commission for Science and Technology Lilongwe Malawi.
National Statistics Office: Malawi (2011) *Trade statistics brief release Mid Year (January – June, 2011) Provisional*. National Statistics Office. Zomba
Available from:< http://www.nso.malawi.net/ > [Accessed 6 October 2011].

NEP (2003) *National Energy Policy 2003*. Department of Energy Affairs, Lilongwe Malawi.

NEPAD (2014) *Guidelines for the NEPAD Climate Change Fund.* [online]. Available from: < http://caadp.net/sites/default/files/documents/CAADP-Programmes/NEPAD-Climate-Fund/English/Guidelines_for_Applicants_(NEPAD_Climate_Change_Fund)_English.pdf > [Accessed 8 October 2015].

Neuman, W.L. (1994) *Social research methodology: Qualitative and quantitative approaches.* (Second Edition). Allyn & Bacon: MA

Nji, R. and Cameroon, B. (2006) What alternatives to oil in Africa? *Africa Renewal.* [online]. Available from:< http://www.un.org/africarenewal/magazine/october-2006/what-alternatives-oil-africa> [Accessed 5 June 2013].

Nkomo, J.C. (2009) Energy security and liquid fuels in South Africa. *Journal of Energy in Southern Africa , (20)1.*
Available from;< http://www.erc.uct.ac.za/jesa/volume20/20-1jesa-nkomo.pdf > [Accessed 20 February 2014].

Nkomo, J.C. (2010) Crude oil price hikes and issues for energy security for Southern Africa. *Journal of Energy in Southern Africa* ,(21)2 Available from:< http://www.erc.uct.ac.za/jesa/volume21/21-2jesa-nkomo.pdf> [Accessed 20 February 2014].

NSO (2014) *Trade Map – Malawi.* [online]. National Statistical Office. Zomba. Available from: < http://www.nsomalawi.mw/data-archives/trade-map-malawi.html> [Accessed 10 November 2015].

O'Kray C. and Kang Wu.K. (2010) Biofuels in China: Development Dynamics, Policy Imperatives, and Future Growth. Available from:<http://www.iaee.org/en/publications/newsletterdl.aspx?id=98> [Accessed 30 June 2015].

Obidzinski, K., Andriani, R., Komarudin, H., Andrianto, A. (2012) Environmental and social impacts of oil palm plantations and their implications for biofuel production in Indonesia. *Ecology and Society.* **17**(1), pp.25. Available from:<http://dx.doi.org/10.5751/ES-04775-170125> [Accessed 26 December 2013].

Oettinger, G. (2012) *EU-Africa energy relations and global energy Markets.* Keynote speech by Energy Commissioner at: *Germany Africa Business Forum* Hamburg, 23 April**.**

OPC/GBI (2014) GBI Sugar Project – Salima. [Letter] Personal communication (11 November 2014).

Orlikowski, W., & Baroudi, J. (1991) Studying information technology in organisations: research approaches and assumptions. *Information Systems Research,* 2(1), pp. 1-28.

Orr, A., Mwale, B.,and Saiti-Chitsonga, D. (2009) Exploring seasonal poverty traps: the 'six-week window' in southern Malawi. *Journal of Development Studies.* (45), pp. 227- 255.

Oyedepo,S.O. (2012) Energy and sustainable development in Nigeria: the way forward. *Energy, Sustainability and Society.* (2)15. Available from :< http://www.energsustainsoc.com/content> [Accessed 14 February 2013].

Pacini, H., Batidzirai, B. (2012) The development of biofuel capacities—strengthening the position of african countries through increased energy security. In: Johnson, F.X., Seebaluck, V. (Eds.), Bioenergy for sustainable development and international competitiveness: the role of sugar cane in Africa. pp. 331-349. Routledge/Earthscan, London,

Palacio, L. D. (2000) *Energy and Transport A European Strategy for Sustainable Development in the 21st Century.* Available from: < http://europa.eu/rapid/press-release_SPEECH-00-114_en.htm> [Accessed 26 April 2016].

Pandey, A., Larroche, C., Ricke, S.C., Dussap, C., Gnansounou, E. (ed.) (2011) *Biofuels : alternative feedstocks and conversion processes*. [online]. Elsevier Science, ProQuest Ebook Central, Available from :< http://ebookcentral.proquest.com/lib/bolton/detail.action?docID=739028. > [Accesssed 24 January 2018].

PIL (2009) Fuel Import Statistics 2009, PIL.

PIL (2011) Fuel Import Statistics 2009, PIL.

Pippard, T. (2010) ‘Oil-Qaeda’: jihadist threats to the energy sector. [online] *Perspectives on terrorism*.(4)3 Available from: < http://www.terrorismanalysts.com/pt/index.php/pot/article/view/103/html> [Accessed 5 May 2016].

Pham. N. (2014) *Sugar industry report*. Available from: < http://fpts.com.vn/FileStore2/File/2014/07/03/Sugar%20industry%20report.pdf > [Accesed 23 September 2015].

Philips, D.C. (1987). *Philosophy, science, and social enquiry: Contemporary methodological controversies in social science and related applied fields of research.* Pergammon Press Oxford, England.

Porter, M. E. (1994) Toward a dynamic theory of strategy. *Strategic Management Journal* (12) Special Issue, pp. 95–117.

PressCane Limited Audited Accounts (2006 – 2010), DELOITTE**.**

PressCane Limited (2004 – 2012) Board Packs.

Purchas, C. and Hutchinson, A. (2008) Consumer information on biofuel sustainability: options for informing consumers on biofuel sustainability. *Bioenergy Association of New Zealand.* Available from: < http://www.bioenergy.org.nz/documents/liquidbiofuels/consumer-info-on-biofuels-sustainability-08.pdf > [Accessed 10 February 2013].

Rastogi, V. (2011) Abellon paving its way in Africa. Presented at: *World Biofuels Markets Conference.* Rotterdam, 24 March 2011. Available from: < http://www.environmental-expert.com/resultEachPressRelease.aspx cid=33596&codi=192145 > [Accessed 27 August 2015].

Remenyi, D., Williams, B., Money, A., and Swartz, E. (1998) *Doing research in business and management: an introduction to process and method***.** London: Sage.

Reserve Bank of Malawi (2011) *Annual report*. 2010. Blantyre, Reserve Bank. Available from:< http://www.rbm.mw > Accessed [6 October 2011].

Reserve Bank of Malawi (2011) *Monthly economic review february 2011*. Blantyre: Reserve Bank. Available from:< http://www.rbm.mw/economic_reviews.aspx > Accessed [6 October 2011].

Robinson, D. (2009) *My Experience Oil Crisis* - 1979 Available from:<http://crudeoilpeak.info/my-experience-oil-crisis-1979> >[Accessed 18 November 2013].

Robinson, D. (2009) *Renamo, Malawi and the struggle to succeed Banda: Assessing theories of Malawian intervention in the Mozambican civil war.* University of Western Australia. Available from:<http://arts.monash.edu.au/publications/eras/edition-11/articles/drobinson.pdf > [Accessed 14 May 2013].

Robinson, B. and Wakeford, J. (2013) Oil shock vulnerabilities & impacts: case study of Malawi. Prepared for: *United Kingdom Department for International Development.*

Robson, C. (1993) *Real world research.* Oxford, Blackwell.

Rosenthal, S.B. and Bourgeois P.L. (1980) *Pragmatism and phenomenology: a philosophic encounter.* B.R.Gruner Company, Amsterdam. Available from:< http://benjamins.com/#catalog/books/zg.89/preview> [Accessed 17 March 2015].

Rudnick, H, Barroso, L, Mocarquer, S, and Bezerra, B (2008), 'A delicate balance in South America', *IEEE Power And Energy Magazine*,[online] (6) 4, pp. 22-35. Available from:< http://web.ebscohost.com/ehost/detail?vid=5&hid=25&sid=d0bb7e51-8939-493e-8d0a-312614b5552c%40sessionmgr4&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d#db=eoah&AN=16710735> [Accessed 15 January 2013].

SADC Sugar Digest (2014) Key sugar projects in Southern Africa. Available from :< http://www.sadcsugardigest.com/key-sugar-projects-in-southern-africa/ > [Accessed 4 December 2014]

Saka, J., Campbell, B., Mkandawire, G., Mphembera, A., Nyirenda, S., Kafoteka, D., Sajidu, S., Mtaula, G. (2005) *Physicochemical characteristics and performance of ethanol –unleaded petrol blends.* Department of Energy Affairs Task Force on introduction of unleaded petrol in Malawi.

Salimi, Z and Kandadi, K.R.(2009) *Customer Knowledge management and demand fulfilment in global supply chains.* BLIS centre , The University of Bolton, Bolton, UK Available from: < https://elearning.bolton.ac.uk/login/index.php> [Accessed 10 February 2013]

Sankhulani, L. N. (2007) G*ender equity through unicef intervention: social capital and capabilities in two selected malawian schools*. PhD, University of Saskatchewan.

Saunders, M., Lewis, P., Thornhill, A. (2000) *Research methods for business students*. 2nd ed.Essex, England: Pearson Education Limited.

Saunders, M., Lewis, P. and Thornhill, A. (2009) *Research methods for business students* 5th ed. Essex, England: Pearson Education limited.

Schein, E. (1992) *'Coming to a new awareness of organisational culture'*, In: Salaman, G., *Human Resource Strategies*, London, Sage.

Seebaluck, V. and Johnson, F.X. (2012) *Bioenergy for sustainable development and international competitiveness: the role of sugarcane in Africa*. Routledge

Sensoz, S., Angin, D., Yorgun, S. (2000) Influence of particle size on the pyrolysis of rapeseed (Brassica napus L.): fuel properties of bio-oil. *Biomass Bioenergy*. (19), pp. 271–279. Available from: < http://www.sciencedirect.com/science/article/pii/S0961953400000416> [Accessed 10 September 2015].

Serageldin, I. (1996) Sustainability as Opportunity and the Problem of Social Capital. *3 Brown J. World Aff.* (III) 2, pp.187-203. Available from: < http://heinonline.org/HOL/Page?handle=hein.journals/brownjwa3&div=73&g_sent =1&collectio n=journals >. [Accessed 10 September 2015].

Sheehan J., Camobreco V., Duffield J., Graboski M., Shapouri H (1998) *An overview of biodiesel and petroleum diesel life cycles.* [online]. US Department of Agriculture and Energy, Washington, DC. Available from: < http://www.nrel.gov/docs/legosti/fy98/24772.pdf> [Accessed 10 February 2013].

Shinoj, P. et al (2011) *Policy Brief 36 Biofuels in India: Future Challenges.* New Dehli. Available from: <http://www.ncap.res.in/upload_files/policy_brief/pb36.pdf> [Accessed 10 February 2013].

Sikdar, S. K. (2003) Sustainable development and sustainability metrics. *AIChe Journal.* 49(8), pp.1928-1932. Available from:< http://dx.doi.org.10.1002/aic.690490802> [Accessed 10 February 2013].

Simon, H.A. (1960) *The New science of management decision***.** New York, NY: Harper and Row.

Singh, R., Murty,H., Gupta,S., Dikshit, A. (2009). An overview of sustainability assessment methodologies. *Ecological Indicators.* 9(2), pp.189-212.

Sissine, F. (2010) *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis*. Technical Report EPA-420-R-10-006. Assessment and Standards Division, Office of Transportation and Air Quality.

Smeets, E., Junginger, M., Faaij, A., Walter, A., Dolzan, P. (2006) *Sustainability of Brazilian bio-ethanol.* Report NWS-E-2006-110, University of Utrecht. Available from: < http://www.neema.ufc.br/Etanol25.pdf> [Accessed 5 January 2014].

Smith, M.F. (1983) *Sampling Consideration in Evaluating Cooperative Extension Programs, Florida Cooperative Extension Service Bulletin, PE-1*, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL.

Somekh, B. and Lewin, C. (2005) *Research methods in the social sciences*. London: Sage.

Sorda, G., Banse, M., Kemfert, C., 2010. An overview of biofuel policies across the world. *Energy Policy*. (38) 11, pp.6977–6988. Available from: < http://dx.doi.org/10.1016/j.enpol.2010.06.066> [Accessed 22 October 2015].

Spencer, C. (2011) Clarifying the Potential of Bioenergy. Presented at: *World Biofuels Markets Conference.* Rotterdam, Netherlands, 24 March 2011.

Stacey, R. (1992) *Managing chaos: dynamic business strategies in an unpredictable world*. London: Kogan Page.

Stake, R.E. (2000), *"Case studies"*, in Denzin, N.K. and Lincoln, Y.S. (Eds), *Handbook of Qualitative Research*, 2nd ed., Sage Publications, Thousand Oaks, CA.

State House Malawi (2015) State of the nation address by Malawi President at the opening of parliament and 2015 – 2016 budget meeting. [online]. Available from: < (http://www.statehouse.mw/state-of-the-nation-address-by-malawi-president-at-the-opening-of-parliament-and-2015-2016-budget-meeting/> [accessed 6 August 2015].

Sun, Y. and Cheng, J.J. (2005) Dilute acid pretreatment of rye straw and bermuda grass for ethanol. *Bio resource Technology*. (96), pp. 1599–1606. Available from: < http://www.tandfonline.com/action/showPopup?citid=citart1&id=CIT0080&doi=10.1080/15435070802107322 > [Accessed 14 October 2011].

Sundu, Y. (2012) Fuel scarcity hits Lilongwe. *THE NATION.* 12 September 2012.

Swannell, J. (ed) (1992) *The oxford morden dictionary english dictionary*, Oxford: Clarendon Press.

Swinbank, A. (2009) EU support for biofuels and bionenergy, ‘environmental sustainability’ criteria, and trade policy. *Dialogue on “Biofuels, Trade Policy and Sustainable Development” Geneva, 17 June 2009.* Available from:< http://ictsd.org/downloads/2009/06/swinbank.pdf > [Accessed 9 March 2014].

Tafirenyika, M. (2013) What went wrong? Lessons from Malawi’s food crisis: Autocracy and aid dependency killed an agriculture success story. *Africa Renewal*. [online]. January 2013 , page 9. Available from: < http://www.un.org/africarenewal/magazine/january-2013/what-went-wrong-lessons-malawi%E2%80%99s-food-crisis > [Accessed 9 October 2015].

Taheripour, F., Zhuang, Q. , Tyner, W.E. and Lu, X. (2012) Biofuels, cropland expansion, and the extensive margin. *Energy, Sustainability and Society.* [online]. , (2)25. Available from : < http://www.energsustainsoc.com/content/2/1/25> [Accessed 14 February 2013].

Takavarasha, T., Uppal, J., and Hongo, H. (2005) A Feasibility study for the production and use of biofuel in the SADC Region. Available from:< http://www.compete-bioafrica.net/policy/060106-SADC%20Biofuels%20Study%20Final%20Report.pdf> [Accessed 5 February 2017].

Tashakkori, A. and Teddlie, C. (1998), *“Mixed methodology: combining qualitative and quantitative approaches*”. London, Sage Publications.

Taylor & Bogdan (1998). *Introduction to qualitative research methods*, 3rd Edition John Wiley: NY

Teddlie, C. and Tashakkori, A. (2006). A general typology of research designs featuring mixed methods. *Research in the Schools, 13*(1), pp.12-28.

Thurnstrom, A., Erasmus, J., Miles, K., Majnoni, A., Alberts, S., Silva, J., Jansen, W., Ndugu, B., Saludeen, D. (2013) *Oil and gas in africa africa's reserves, potential and prospects.* KPMG. Available from: < http://www.kpmg.com/Africa/en/IssuesAndInsights/Articles-Publications/Documents/Oil%20and%20Gas%20in%20Africa.pdf> Accessed [27 April 2013].

Thai K.V (2001) Public Procurement Re-Examined. *Journal of Public Procurement*. (1)1, pp. 9-50.

TheGlobalEconomy.com (2017) Malawi oil consumption. Available from:< http://www.theglobaleconomy.com/Malawi/oil_consumption/> [Accessed 1 March 2017].

Tiffany, D.G. (2009) Economic and environmental impacts of u.s. corn ethanol production and use. federal reserve bank of st. Louis. *Regional Economic Development. 5(1) 2009.*

Trindade,S.C. (2009) The Sustainability of Biofuels Depends on International Trade. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects. (*31)18, pp.1680-1686*.* Available from;< http://dx.doi.org/10.1080/15567030903022010> [Accessed 5 June 2013].

Trines, E. et al. (2006) *Integrating agriculture, forestry and other land use in future climate changes: methodological issue and policy options.* Climate change, scientific assessment and policy analysis (WAB). Netherlands, pp. 154.

Umbach, F. (2010) Global energy security and the implications for the EU. *Science Direct Journal* 38(3), pp.1229-1240. Available from:< http://dx.doi.org/10.1016/j.enpol.2009.01.010 > [Accessed 5 June 2013].

UNCTAD, 2011. Review of Maritime Transport. Geneva United Nations Conference on Trade and Development, UNC-TAD/RMT/2011, [Online]. Available from: < http:// www.unctad.org > [Accessed 27 October 2015].

United Nations (2014) Energy statistics.[online]. Available from: < https://www.quandl.com/data/UENG/RF_MWI-Fuel-Oil-Malawi > [Accessed 29 September 2015].

US-EPA, (2010).*Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.* U.S.Environmental Protection Agency, EPA-420-R-10-006. Available from: < https://scholar.google.com/scholar?q=Renewable+Fuel+Standard+Program+%28RFS2%29+Regulatory+Impact+Analysis+F+Sissine+-+2010+-+Technical+Report+EPA-420-R-10-+&btnG=&hl=en&as_sdt=0%2C5> [Accessed 14 October 2016].

Van Zyl, E. (2007) Biofuels production from Plant Biomass in southern Africa. Presented at: *Green Power Conference* Cape Town, South Africa. 5 – 7 November 2007.

Vedanthachari, L.(2007) *An Investigation into the benefits accrued by medium sized manufacturing enterprises Implementing ERP,CRM and e-procurement Technologies*. PhD, University of Bolton.

Voegele, E (2014) OECD – FAO outlook report predicts growth in ethanol production. *Ethanol Producer Magazine*. [online] Available from: < http://ethanolproducer.com/articles/11264/oecd-fao-outlook-report-predicts-growth-in-ethanol-production > [Accessed 24 August 2015].

Wambua, C. (2011) Laws and Policies Enabling the Production of Biofuels in Malawi. PISCES Working Brief No. 4, [Online]. Available from: < www.pisces.or.ke> [Accessed 24 August 2015].

Waterland,L.R., Venkatesh,S., Unnasch, S. (2003) *Safety and performance assessment of ethanol/diesel blends (E-Diesel)***.** National Renewable Energy Laboratory, Cupertino California.
Available from: < http://www.nrel.gov/docs/fy03osti/34817.pdf> [Accessed 14 August 2011].

West Texas Intermediate (2017) Crude oil prices [online].
Available from:< http://www.macrotrends.net/1369/crude-oil-price-history-chart> [Accessed 1 March 2017].

White, B. (2002) *Writing your MBA dissertation*. London: Continuum.

Wittgenstein, L. (1968) *Philosophical investigations*. 3rd ed. G.E.M. Anscombe, Trans. New York, NY.

Woll, H. (2013) Process diary as methodological approach in longitudinal phenomenological research. *Indo-Pacific Journal of Phenomenoloy 13(2),* pp.11*. Available from:* < http://www.ipjp.org/index.php?option=com_jdownloads&Itemid=318&view=finish&cid=250&catid=57&m=0> [Accessed 5 January 2014].

Woods, J.(2000) *Intergrating sweet sorghum and sugarcane for bioenergy: modelling the potential for electricity and ethanol production in se zimbabwe.* PhD. King's College, London. Available from: < http://www.sorghum.silvaeculture.co.uk/Woods2001ESD.pdf > [Accessed 10 October 2015].

World Bank (2015) Malawi data: World Development Indicators. Available from:< http://data.worldbank.org/country/malawi> [Accessed 10 October 2015].

World Petroleum Council (2009) Alternative Transport Fuels. *AIP*. Available from: < http://www.world-petroleum.org/index.php?/Technology/alternative-transport-fuels-courtesy-of-aip.html> [Accessed 7 June 2012].

Wyne-Jones, S. (2003) Ethanol gelfuel as efficient alternative energy source. *LAMNET-NEWS (3).* Available from: < http://www.bioenergy-lamnet.org/publications/source/LamnetPublications/5-Wynne-Jones.pdf> [Accessed 25 July 2011].

Xavier, M. R. (2007) The Brazilian sugarcane ethanol experience. *Competitive Enterprise Institute*, pp.14. Available from: < https://www.cei.org/pdf/5774.pdf> [Accessed 11 October 2015].

Yilmaz A.O. (2008) Renewable energy and coal use in Turkey. *Renewable Energy, (*33) 5, pp. 950-959.
Available from: <http://dx.doi.org/10.1016/j.renene.2007.04.022> [Accessed 1 April 2013].

Ziba, M. (2010) Shire-Zambezi water way opens up southern Africa. *Africa News.* [online] Available from: < http://www.afrika.no/Detailed/19750.html> [Accessed 6 August 2015].

APPENDICIES

I. QUESTIONNAIRE

QUESTIONNAIRE:

1. **Determine how to increase ethanol production volumes to become significant in the liquid fuels portfolio.**

- How do you think adequate fuel supplies can be assured in Malawi in the long term?
- What role do you think ethanol could play in the liquid fuel portfolio in Malawi? Do you see any synergies between ethanol and fossil fuel or Are you aware of any biofuels in use in Malawi? List them.
- Do you think ethanol volumes should be increased in Malawi? Why? What are the benefits?
- What policy changes should be instituted to promote ethanol production in Malawi?
- Do you think the policy environment is clear on liquid fuels with regards to ethanol?
- Do you think incentives should be offered to increase ethanol production in Malawi? If yes why and what incentives?
- Are you aware of any existing biofuels production facilities in Malawi? Name them.
- Globally many crops are used for renewable fuel production. Do you know any viable energy crops in Malawi (sorghum, sugarcane, jatropha)? Name them.

2. **Determine a possible optimal portfolio of liquid fuels in Malawi.**

- Malawi imports approximately 110 million litres of petrol and roughly 225 million litres of diesel every year. Given these volumes what do you think should be the volume of ethanol available?
- Do you consider ethanol as a replacement of fossil fuels or complimentary to fossil fuels? Why?

- Do you have any information regarding a Government initiative or programme to increase the uptake of ethanol?

3. Determine the potential contribution of ethanol to the economy.

- Ethanol production in Malawi has been going on for over 30years, has it made any difference?
- Do you think it is advantageous or not to use ethanol as a fuel? Why?
- Do you have information regarding diesel blending with ethanol or experience with this type of blending? Would you recommend it for Malawi?

4. Establish sustainability criteria of ethanol production in Malawi.

- Do you think Malawi is doing enough to promote ethanol as a bio-fuel? If not what more can be done?
- Do you think there is a policy to coordinate biofuels and fossil fuels?
- What criteria would you consider in determining that a bio-fuel is sustainable or not? (Table to complete).

II. QUESTIONNAIRE – SUSTAINABILITY

ETHANOL PRODUCTION SUSTAINABILITY CRITERIA FOR MALAWI

Please tick the number that best fits your opinion for each criterion listed. Add as many other criteria and rate them as well.

ETHANOL PRODUCTION SUSTAINABLITY CRITERIA	1 Not relevant at all	2 Mostly not relevant	3 Neither relevant nor irrelevant	4 Mostly relevant	5 Absolutely relevant	Add comment to clarify
Positive contribution to Malawi liquid fuel volume						
Affects air pollution						
Competition with food crop land						
Affects water pollution						
Affects soil erosion						
Affects price of land						
Affects forests						
Affects forex availability						
Affects food prices						
Contributes to job creation						
Reduces use of charcoal						
Affects energy security						
Increases water usage						
Affects national import costs						

Reduces oil dependence						
Positive impact on economy						

III: Conference paper

"Proceedings of the strategic research for economic growth and social change in Malawi conference". A University of Bolton Conference which was held at Malawi Institute of Management from 21st -22nd June, 2013, Lilongwe

"Towards an Optimal Product Portfolio of Liquid Fuels for the Malawi Energy Market: A Study to develop a strategic framework for a biofuel producer"

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1. Abstract

Ethanol use either as a blend in petrol or as a standalone fuel has come into sharp focus in Malawi recently driven by the inadequate supply of fossil fuels (petrol and diesel) resulting in persistent fuel queues, coupled with unprecedented price volatility.

The paper examines how the volume of ethanol can be increased in the liquid fuel portfolio with its attendant benefits.

Primary data collection consisted of interviews with strategists in the energy sector including energy regulators and policy makers, fossil liquid fuel importers, biofuel producers and alternative energy producers. Archival research was also employed. Mixed methodologies were used to analyze the quantitative and qualitative data.

The research confirms that ethanol fuel volumes have a significant role in reducing imported fossil fuel dependency which is the largest import bill at 16.5%.

Energy security is increased via improved fuel volumes from blending at the mandatory 20% level. Sustainability criteria themes of land use change (LUC) or indirect land use change (ILUC), food versus fuel were highly debatable. Climate change issues for ethanol production emerged as important.

Land use change issues do not apply in the case of ethanol produced in Malawi from molasses. Similarly, there is no contest between food and fuel.

The strategic framework developed for increasing the role of ethanol in the liquid fuels portfolio puts economic contribution in the driving seat together with energy security and climate change mitigation.

Limitations of the research were the scarcity of biofuels literature in Malawi and targeted interviews due to time and cost constraints to interrogate further the highly debated responses.

Key words: sustainability, land use change, indirect land use change

2. Introduction

Energy has an important strategic bearing on the success of economic developments in any country (NEP, 2003). In this regard Malawi is no exception and the country expects “reliable, sustainable and affordable energy” (MDGS, 2006, p.23). The scarcity of energy resources particularly liquid fuels continues to be a major concern (DAILY TIMES, 18 November 2012). Ethanol has been cited by Government ministers as a solution for liquid fuel shortages in Malawi (Nation, January 2013). The projected energy profile for Malawi in 2000 shows biomass (vegetable matter or plant residues used as a source of energy) as the leading energy resource at 93% with liquid fuel (including ethanol) a distant second at 3.5% followed by electricity at 2.3%, coal at 1% and other renewables (solar and wind) are at 0.2% (NEP, 2003). Liquid fuels in Malawi include fossil products such as petrol, diesel, paraffin, aviation gas and ethanol the only biofuel (NEP, 2003).While the projections represent a wish list by policy makers as to what the optimal energy portfolio ought to be, the reality is that liquid fuels continue to occupy a significant place, second only to biomass. The National Statistics Office reveals that petroleum imports at MK13.94 billion for the first half of 2010 topped the list of imports and accounted for 16.5% of the import bill for Malawi followed by medical supplies at 16.1% and fertilizer came third at 8.6% (National Statistics Office, 2011). The challenge is how to strategically manage the energy mix and in particular how to optimize the liquid fuels portfolio for the benefit of the economy in a sustainable manner. According to the NEP (2003) inadequate blending of ethanol and petrol in the ratio of 20% ethanol and 80% petrol is one cause of inefficiency in the liquid fuels supply (p.28, p.30, p.73). "Malawi imports 97% of its refined petroleum, the balance is contributed by locally produced ethanol, sold directly to the oil companies for blending with petrol on a maximum 20:80 ratio of ethanol-petrol ……nearly 7% of the total liquid fuels market". (NEP 2003, p.73).

The research purpose is to develop a strategic framework for sustainably increasing the volume of ethanol in the Malawi liquid fuel portfolio to reduce dependence on fossil fuels (NEP, 2003).

3. Literature review

Increasingly issues of sustainable energy production are being investigated by energy producers, academicians, politicians and the general public. Even though energy is not mentioned as a separate MDG, energy services are an essential element in economic development and poverty reduction (Goncalves et al, 2011). In this section the researcher briefly reviews sustainability factors that could be relevant to ethanol production.

3.1 Sustainability Criteria

According to Trines et al. (2006) cited by Fumo (2009), assessing sustainability involves identifying environmental, economic and distributional or social criteria.

Purchas and Hutchinson (2008, p5) go further, in their report on biofuel sustainability defined it as "the ability to produce biofuels to contribute to today's fuel needs without compromising the ability of productive land to meet current and future food and fuel needs". Issues considered under the sustainability banner include environmental (land use change, fertilizer use, biodiversity, energy intensity), social (labour conditions, land ownership) and economic (net benefit).

According to Barber et al (2008, p6) "sustainability criteria are generally poorly defined". Broad sustainability criteria by Barber et al (2008) embrace the following:

a) Greenhouse gas (GHG) emissions and energy balance
b) Sugarcane production (land use (LUC or ILUC), fertilizer,water use, agrichemicals, mechanization)
c) Flora and fauna protection (biodiversity, forests)
d) Ecological impacts (GHGs emissions = air pollution, water pollution, soil erosion)
e) Economic impacts (food vs fuel and land prices, costs)

European Parliament, Council (2009) Directive 2009/28/EC specifies criteria similar to those noted by Barber (2008). The directive seeks to encompass imported biofuels as well. According to Mitchell (2010, p110) "Ethanol produced from sugarcane or molasses directly benefits from duty-free access and should meet the EU's default minimum criterion for reducing GHGs".

To sum it up Barber et al (2008) add that it is possible to set various sustainability criteria but "to collect sufficient information" or data is difficult.

Safeguarding biodiversity is another of the criteria mentioned and Groom et al (2008) mention in very broad terms that land under biofuel crops must be minimized.

According to Shinoj et al (2011) the Indian National Biofuels Policy side steps the controversial issue of food versus fuel by entrenching in the policy that food related feedstocks would not be permitted, in order to avoid a conflict between food security and energy security. Notably ethanol from sugar cane molasses is included as coming from a non-food feedstock.

Jumbe et al. (2007) confirms that environmental and economic dimensions of biofuels have received wide attention in biofuel policies and assessments. Continuing debates over for example the effect of biofuel on food prices (fuel versus food) and over large versus small-scale biofuel production demonstrate the non-universality of the sustainability criteria. WBM (2013) presentations by industrialists, environmentalists and policy makers demonstrate the clash of views between business interests, ideological and other emotive beliefs.

The literature shows that certain criteria are more frequently referred to than others indicating an attempt at consensus in the ordering of sustainability criteria is emerging but not finalized. Generally GHGs (or climate change issues), ILUC and economic benefit are at the top of many lists.

3.2 Increasing Ethanol Production

According to NEP (2003) increasing ethanol volume in the liquid fuel portfolio via mandatory blending is a pathway to reducing dependence on fossil fuels. A study by Cho et al (2011) found that renewable energy increases in the liquid fuel mix led to a decrease in fossil oil consumption in Asia. Calvacanti (2011, p2) says there is huge potential "in the sugar industry for the production of ethanol as an alternative to fossil fuels". Energy security and economic development are enhanced to the extent that fossil fuel dependence is reduced by increases in renewables and particularly ethanol. The sustainable production of ethanol is dependent on the availability of feedstock. In this connection the EU strategy (European Parliament, Council, 2009) for promoting biofuel use explicitly mentions expanding feedstock supplies (article 89).

According to Mitchell (2010) an economic development strategy must include ethanol production feedstock. As more feedstock becomes available the ethanol production costs will decrease and contribute to economic growth.

Studies (Rao and Bantilan, 2007; Reddy et al., 2005) quoted by Shinoj et al (2011) indicate that sweet sorghum can be used as an alternative or complimentary feed stock to sugar cane. Other feed stocks such as bagasse, crop residues etc commonly called second and third generation biofuels could also provide a long term solution (Raju et al., 2009).

Friends of the earth and other such groupings are often scathing in their denunciations of biofuel production as causing deforestation, rising food prices and other negative economic impacts. The reference is to first generation biofuels (Raju et al, 2009). As expected the most comprehensive response comes from the Brazilian Sugarcane Industry Association, who is the world leader in biofuel production (Er, 2011). In response to these allegations Jank (2008) points out that the information used is often out of context and incomplete. In the end these organizations will lose credibility as the facts become evident. The Brazil biofuel success story is offered as proof. The hundreds of visits to Brazil in recent months by groups of government and elected officials, researchers, students, journalists and investors from all over the world bear testimony (Jank, 2008). There is controversy on indirect land use change (ILUC), an hypothesis that the rapid expansion of biofuel production in recent years is driving up the overall demand for agricultural land (Dunmore, 2011). However Brazil is a global reference point for a successful ethanol production program.

In pursuing sustainable ethanol production it is evident from literature that sustainability is important. The questions arising are therefore:

a) What factors make for sustainable ethanol production in Malawi?

b) How can ethanol production volumes be increased in Malawi?

4. Research methodology and design

According to Collis and Hussey (2003) using both qualitative and quantitative methods for collecting data have advantages in providing qualitative insights. In the current research a search of industry and government records and documents will provide quantitative data as to what volumes of biofuels exist in the Malawi liquid fuels mix, while questionnaires and semi-structured interviews of the various stakeholders would illuminate the rationale behind the numbers. The use of different methods, techniques and approaches in research is called triangulation (Collis and Hussey, 2003). Jick (1991) argues that triangulation has vital strengths such as enhancing qualitative methods and allowing the complimentary use of quantitative methods. The strategy to be used for data collection in this research will be mixed. This is a justified way of conducting research as these approaches and strategies are interdependent (Saunders et. al. 2000).

4.1 Data Collection

According to Saunders et.al. (2000) the use of a questionnaire (or survey) is a popular and common strategy in business and management research. Much valuable information can be collected which is easily understood. The downside of this strategy is that time has to be taken to pilot the questionnaire. In this research this is mitigated by the relatively small population.

Sankhulani (2007) quoting Bernard (2000) outlines types of questionnaires that can be administered as follows, face-to-face questionnaire, the self-administered questionnaire, and the telephone interview. The choice of the survey method in this research will be largely the self-administered questionnaire and semi-structured interviews The advantage being that the number of stakeholders is deemed small.

Questionnaires were administered personally to officials in the energy sector as follows:

a) Malawi Energy Regulatory Authority - Regulator
b) Department of Energy – Policy Maker
c) Electricity Supply Commission of Malawi (ESCOM) – Alternative energy producer.
d) National Commission of Science and Technology (NCST) –research Organization
e) Malawi Bureau of Standards (MBS) – Standards Organisation
f) Bio-energy Resources Limited (BERL) – Biofuel (biodiesel) producer
g) Ethanol Company Limited (ETHCO) - Biofuel (ethanol) producer

Semi structured interviews were also conducted with officials in the same organizations with the same officers to clarify certain responses and obtain deeper insights.

Information was collected in order to establish what the energy strategists considered important biofuel production sustainability criteria in the Malawi context.

4.2 Data Analysis

Analysis of the data was manually done and the table (TABLE 1) shows the frequency ranking of the criteria as viewed by the strategists in the targeted organizations. The criteria for sustainable ethanol production developed by Fumo (2009) provide a launch pad for this analysis.

FREQUENCY OF HIGHEST RATINGS

ETHANOL PRODUCTION SUSTAINABLITY CRITERIA	1 Not relevant at all	2 Mostly not relevant	3 Somewhat relevant	4 Mostly relevant	5 Absolutely relevant	
Positive contribution to Malawi liquid fuel volume as an import substitute						
Improves air quality (pollution) through emissions reduction						
Land use: Competes with						

food crops						
Protects water quality (pollution)						
Affects soil erosion						
Affects price of land						
Affects biodiversity (forests)						
Affects forex availability as an import substitution						
Affects food prices						
Contributes to job creation						
Reduces use of charcoal						
Improves energy security						
Increases water usage						
Affects national import costs						
Reduces dependence on imported oil (serves as petrol import substitution)						
Positive impact on economy						

Affects Government policies and directives						
Impacts on local culture - social welfare						

TABLE 1

4.3 Ethics

To maintain ethical standards of research Salimi and Kandadi (2009) suggest keeping the details of respondents and their organizations separate from the analysis and conclusions. The privacy of the respondents is thus observed by the author. Stake (2000) support this by stating that “qualitative researchers are guests in the private spaces of the world. Their manner should be good and their code of ethics strict.”

5. Research findings and discussion

The sustainability criteria viewed as most relevant by the respondents are tabulated in TABLE 2. The standard adopted for the relevance rating was a minimum of four out of the five respondents. The justification being the small number of respondents, as stated by Henry (1990) and quoted by Saunders et.al. (2000, p153) “for populations of less than 50 cases probability sampling should not be done. Data should be collected on the entire population to avoid the influence of a single extreme case being more pronounced".

SUSTAINABILITY CRITERIA

RELEVANCE RATING	SUSTAINABILTY CRITERIA	RESPONDENT REMARKS
Absolutely relevant	a) Positive contribution to Malawi liquid fuel volume as an import substitute. b) Improves air quality (pollution) through emissions reduction. c) Affects forex availability through import substitution. d) Contributes to job creation e) Improves energy security f) Reduces dependence on imported oil (serves as petrol import substitution) g) Positive impact on economy	"All in all this ethanol has a net positive effect on the Malawi economy via the positive effects arising from quantity enhancement through blending and price stabilization" "reduces pollution as compared to petrol" " Malawi has a largely unsustainable and narrow foreign exchange "earning" base, being in the form of tobacco and donor support." ".. Malawi has and will continue to diversity its fuel sources thereby improving its fuel security status, a very critical national concern given the country's landlocked nature..."
Mostly relevant	a) Affects soil erosion b) Affects price of land	"may increase soil erosion by opening of new land" " the question of land meant for food crops being appropriated for ethanol feedstock

	c) Affects biodiversity (forests) d) Affects national import costs	production and/or instigating and fueling an escalation in land prices, in the Malawi context and in many other countries' contexts-where sugarcane is grown for ethanol production-for that matter, does not arise."
Somewhat relevant	a) Land use: Competes with food crops b) Protects water quality (pollution) c) Affects food prices d) Reduces use of charcoal e) Increases water usage	Ethanol production cannot necessarily affect food production considering that land used for ethanol feedstock is not automatically suitable for maize production" "My understanding, it is that change from using the land in growing traditional food crops to using more land for cash/energy crops while implementing more efficient use of the dedicated land for food crops." "through irrigation" "if use of ethanol for cooking is promoted"

TABLE 2

All the respondents agreed that ethanol production makes a positive contribution to the volume of Malawi's liquid volume. A strategist in the alternative energy sector captured the economic impact of blending petrol with ethanol as follows "It is huge. As a landlocked country that relies on hauling most of its imports and exports by road, the cost of hauling the liquid fuel like diesel, petrol and paraffin impact heavily on the economy."

There was unanimity that ethanol has a positive net effect on air quality as it reduces pollution.

Sixty percent (60%) agreed that ethanol :

a) mitigates the negative climate change issues and helps Malawi meet its international obligations.
b) has a positive net effect on forex
c) enhances energy security by reducing fossil oil dependence
d) has a net positive effect on the economy
e) does not affect food prices at all

Land use change or issues of food crop land shifting to energy crops had mixed responses. Some did not see any relevance at all while others had no views or knowledge on the subject.

Job creation and water usage were rated by sixty percent (60%) of the respondents as "mostly relevant" as opposed to "absolutely relevant".

6. Conclusions

The results show that ethanol production sustainability criteria in Malawi rank the economic contribution aspect at the top. Energy security is seen as part of the economic benefit. Issues of air quality and climate change were also seen as paramount as shown by the equal rating (100%) with economic contribution.

Land use change (LUC or ILUC) had no consensus among the strategists interviewed. Consistent with the literature review this aspect was highly debatable. Other criteria such as job creation and water usage featured highly but

The sustainability criteria emanating from this research for ethanol production in Malawi include:

a) Making a positive economic contribution

b) Reducing air pollution

c) Having a positive effect on climate change

d) Enhancing energy security

Further interrogation is required because of the interrelatedness of the criteria for example energy security and economic contribution, job creation and economic contribution.

6. References

Barber, A., Pellow, G., Pereira, M. (2008) The Sustainability of Brazilian Sugarcane Ethanol: A Literature Review. Energy Efficiency and Conservation Authority (EECA), New Zealand, pp41. Available from : <http://s3.amazonaws.com/zanran_storage/www.eeca.govt.nz/Content Pages/16021933.pdf> [Accessed 10 December 2012]

BioJet international ltd.; BioJet and abundant biofuels agree to merge. (2011). Energy & Ecology Business, 37. Available from: < http://search.proquest.com/docview/865724866?accountid=9653> [Accessed 14 February 2013]

Crooks, E. (2009, Jul 08). Back to petroleum. Financial Times [online]. Available from <http://search.proquest.com/docview/250217273?accountid=9653> [Accessed 16 January 2013]

Crooks, E. (2009, Nov 05). Wind of change in corridors of power. Financial Times [online].Available from <http://search.proquest.com/docview/250251638?accountid=9653> [Accessed 16 January 2013]

Cressy, N, (2012) Next generation bio-fools. World Biofuels Markets News 25 October 2012 [online]. Available from:< http://worldbiofuelsmarkets.info/?p=1883> [Accessed 27 October 2012]

Demirbas, A (2010) Progress and recent trends in biodiesel fuels. Energy Conversion and Management (50) 1, pp. 14-34. Available from: < http://archive.sciencewatch.com/dr/fbp/2010/pdf/10aprfbpDemi.pdf> [Accessed 15 February 2013].

Demirbas, T., and Demirbas, A. H. (2010) Bioenergy, Green Energy. Biomass and Biofuels. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* (32)12, pp. 1067-075. Available from :< http://search.ebscohost.com/login.aspx?direct=true&db=aqh&AN=49143061&site=ehost-live> [Accessed 14 February 2013].

Du, X., and McPhail, L. L. (2012). Inside the black box: The price linkage and transmission between energy and agricultural markets. *The Energy Journal, 33*(2), pp. 171-194. Available from :< http://search.proquest.com/docview/1002622714?accountid=9653> [Accessed 31 January 2013]

Dunmore, C. (2011) Biodiesel industry rejects EU land use impact study. Available from:<http://www.reuters.com/article/2011/10/07/us-eu-biodiesel-idUSTRE79650W20111007> [Accessed 13 October 2011].

Er, A.C. (2011) A Comparative Analysis of the Brazilian Bioethanol Sector and the Malaysian Palm Biofuel Sector. www.ccsenet.org/ass Asian Social Science Vol. 7, No. 2; February 2011 74 ISSN 1911-2017 E-ISSN 1911-2025. Available from:< http://ccsenet.org/journal/index.php/ass/issue/view/309> [Accessed 12 September 2011]

European Parliament, Council (2009) Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance) Available from: < http://eur-ex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0028:EN:NOT> Accessed [9 Nov 2012]

Fumo, E.L.D (2009) Mozambican Criteria for Sustainable Ethanol Production: Identification, Assessment and Stakeholders Support. MSc Thesis Wageningen University. Available from: < http://www.dgis.wur.nl/uk/zoek.htm?q=fumo&ft=fumo&requiredfields=wv_sitename:www_dgis_wur_nl > [Accessed 10 February 2013]

Mitchell, D. (2010) Biofuels in Africa Opportunities, Prospects, and Challenges. Available from: < http://africaknowledgelab.worldbank.org/akl/sites/africaknowledgelab.worldbank.org/files/report/Biofuels_Full_report.pdf> [Accessed 10 February 2013]

National Energy Policy, 2003

National Statistics Office: Malawi (2011), Trade Statistics Brief Release Mid Year (January – June, 2011) Provisional. Zomba: National Statistics Office. Available from:< http://www.nso.malawi.net/ > Accessed [6th October 2011].

Oyedepo,S.O. (2012) Energy and sustainable development in Nigeria: the way forward. Energy, Sustainability and Society 2012, (2)15. Available from :< http://www.energsustainsoc.com/content> [Accessed 14 February 2013]

Purchas, C. and Hutchinson, A. (2008) Consumer Information on Biofuel Sustainability: OPTIONS FOR INFORMING CONSUMERS ON BIOFUEL SUSTAINABILITY. Available from: < http://www.bioenergy.org.nz/documents/liquidbiofuels/consumer-info-on-biofuels-sustainability-08.pdf > [Accessed 10 February 2013].

Taheripour, F. et. al. (2012) Biofuels, cropland expansion, and the extensive margin. Energy, Sustainability and Society , (2)25. [online]. Available from : < http://www.energsustainsoc.com/content/2/1/25> [Accessed 14 February 2013]

Salimi, Z and Kandadi, K.R.(2009) Customer Knowledge management and demand fulfilment in global supply chains. BLIS centre , The University of Bolton, Bolton, UK
Available from: < https://elearning.bolton.ac.uk/login/index.php> [Accessed 10 February 2013]

Shinoj,P. et al (2011) Policy Brief 36 Biofuels in India: Future Challenges. Available from: < http://www.ncap.res.in/upload_files/policy_brief/pb36.pdf> [Accessed 10 February 2013].

Stake, R.E. (2000), „„Case studies"", in Denzin, N.K. and Lincoln, Y.S. (Eds), Handbook of Qualitative Research, 2nd ed., Sage Publications, Thousand Oaks, CA.

Trines, E. et al. (2006) Integrating agriculture, forestry and other land use in future climate changes: methodological issue and policy options. Climate change, scientific assessment and policy analysis (WAB). Netherland, pp154.

Weiner, R. and Clingan, G. (2012) Brazil is Zooming Ahead on Ethanol. Miami Herald *PR Newswire* [New York] [online]. Available from: <

http://www.weinerpublic.com/20120810.html

> [Accessed 10 August 2012]